# Spring 2010 ICEBridge Flight Plans
# 28 April 2010 Draft

*compiled by*

John Sonntag

# Introduction to Flight Plans

This document is a translation of the IceBridge scientific objectives articulated at the close of the January IceBridge Greenland planning meeting held at NASA's Goddard Space Flight Center, through ad hoc science team telecons and through e-mail communication and iterations into a series of operationally realistic flight plans, intended to be flown by NASA's DC-8 and P-3 aircraft, beginning in late March and ending in late May 2010. The material is shown on the following pages in the distilled form of a map and brief text description of each science flight..

For each planned mission, we give a map and brief text description for the mission, and in the page header we also list the aircraft the mission is designed to be flown with and the base it is to be flown from. At the end of the document we add an appendix of supplementary information, such as more detailed maps of certain missions, composite maps where several missions are designed to work together, and maps of flights performed by other organization which are believed to be relevant to science decisions about these ICEBridge missions.

Note that there are currently several more flight plans shown below, both for the DC-8 and the P-3, than current budgets will allow to be flown this year. We expect to fly 10-12 DC-8 missions, and 10-12 P-3 missions.

General comment to flight plans: During any high altitude transit during the flight lines LVIS will be turned on to gather data. This has been requested by both the ICESat Science Team for calibration and the IceBridge science teams.

**IceBridge Mission Statement**
Operation IceBridge will employ aircraft to monitor the most sensitive and critical areas of sea ice, ice sheets and glaciers during the gap in satellite coverage caused by the failure of ICESat-1, in 2009, and the launch of ICESat-2, planned for late 2015. Sensitive and critical areas include coastal Greenland and especially its outlet glaciers, costal Antarctica including the Antarctic Peninsula and ice shelves, the sea ice of the Arctic and Antarctic and the southeast Alaskan glaciers. Data collected by IceBridge will improve our knowledge of the contribution of the Greenland and Antarctic ice sheets to sea level rise and will make fundamental contributions to the understanding of changes occurring in the extent and thickness of the polar sea ice cover. Given the societal importance of understanding changes in sea level rise and sea ice extent, IceBridge data will monitor and improve modeling efforts for sea ice, ice sheet and glaciers. IceBridge will also prepare for the future of airborne monitoring efforts of the cryosphere by adapting existing instruments for high altitude unmanned aerial systems such as the NASA Global Hawk.

**IceBridge Science Objectives**
The following are the major science objectives of Operation IceBridge in priority order and are meet by the following flight plans:
1) Make airborne laser altimetry measurements over the ice sheets and sea ice to fill in the data gap between the failure of ICESat-1 in 2009 and the launch of ICESat-2 planned for 2015.

2) Link measurements made by ICESat, ICESat-2, and CryoSat-2 to allow their comparison and the production of a long-term, ice sheet altimetry record.

3) Use airborne altimetry and radar to monitor key, rapidly changing areas of ice, including sea ice, ice sheets and glaciers, in the Arctic and Antarctic to maintain a long term observation record, improve understanding of glacial dynamics, and augment predictive models of sea level rise and sea ice cover.

4) In conjunction with altimetry measurements, collect other remotely sensed data to improve predictive models of sea level rise and sea ice cover, especially the following:

- Ice sheet and sea ice thickness, structure and extent;
- Bed topography underlying land-based ice;
- Bathymetry beneath floating ice shelves;
- Snow accumulation and firn structure; and
- Other geophysical constraints that will improve estimates of the geothermal and oceanic heat flux

5) Adapt existing instruments for airborne remote sensing of ice by high altitude unmanned aerial systems such as the NASA Global Hawk.

**IceBridge Contact Phone numbers**

Project Management/Science

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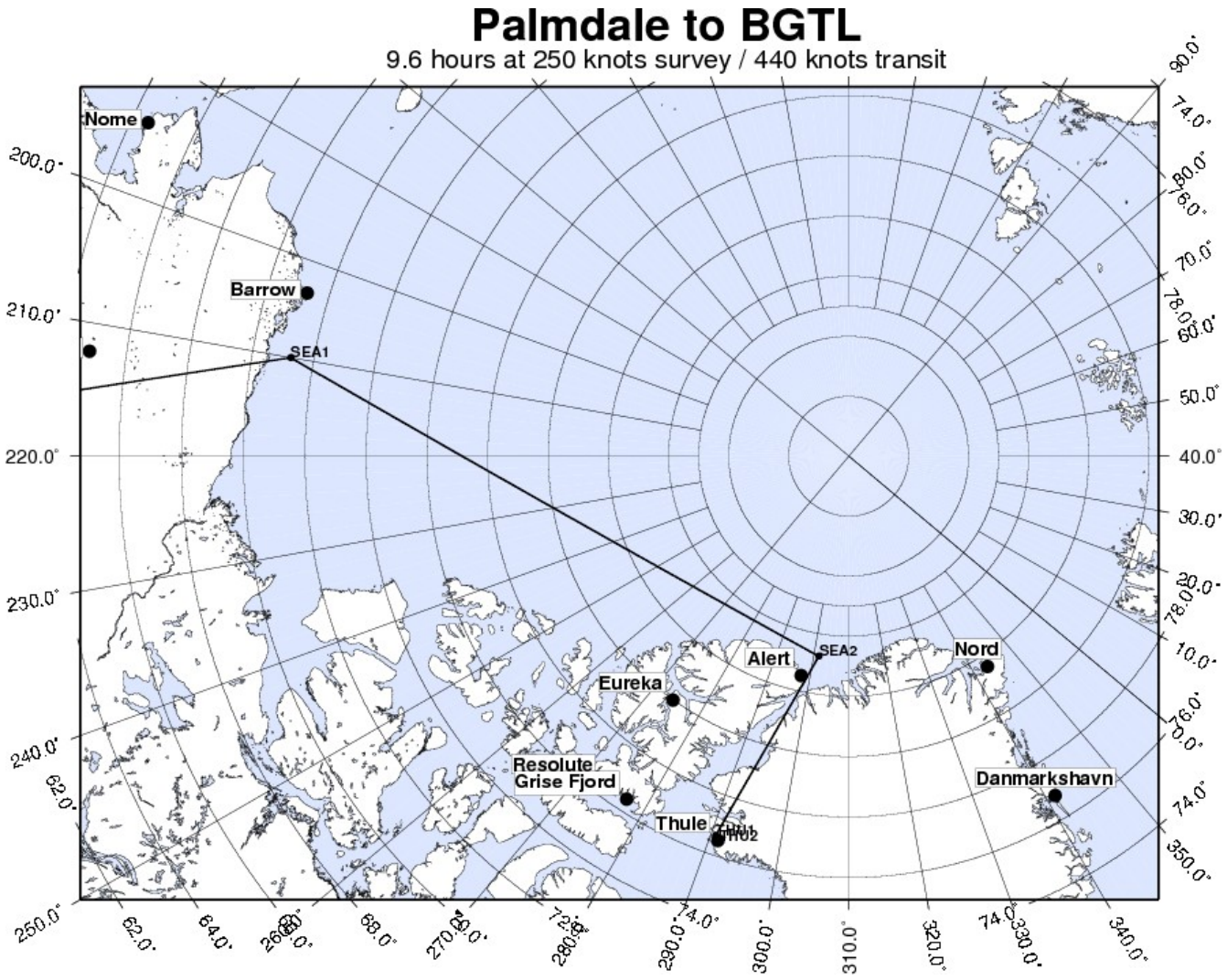
# Palmdale Transit – DC-8 / Palmdale to Thule

This mission is a "target if opportunity" concept, where if the weather forecast over the Arctic Basin looks good, we will fly somewhat out of the way during our transit from Palmdale to Thule and gather high-altitude data (using LVIS) over sea ice on the way. Not shown on the map below are several short lines over glaciers and icefields in southeast Alaska, which are secondary targets of opportunity. If none of the targets appear open, we plan to transit direct from Palmdale to Thule. This flight should be adapted to fly any reasonable transit line across the arctic sea ice that has clear weather on the day of transit. Ron Kwok will be available to help with this weather based decision. Chris Larsen at the University of Alaska-Fairbanks is also available to help with weather predictions over the Southeast Alaskan Glaciers. The Science Team requested a line that is ~50% clear or better.

**Flight Priority:** Low **Instrument Priority:** LVIS

**ICESat Track:** none

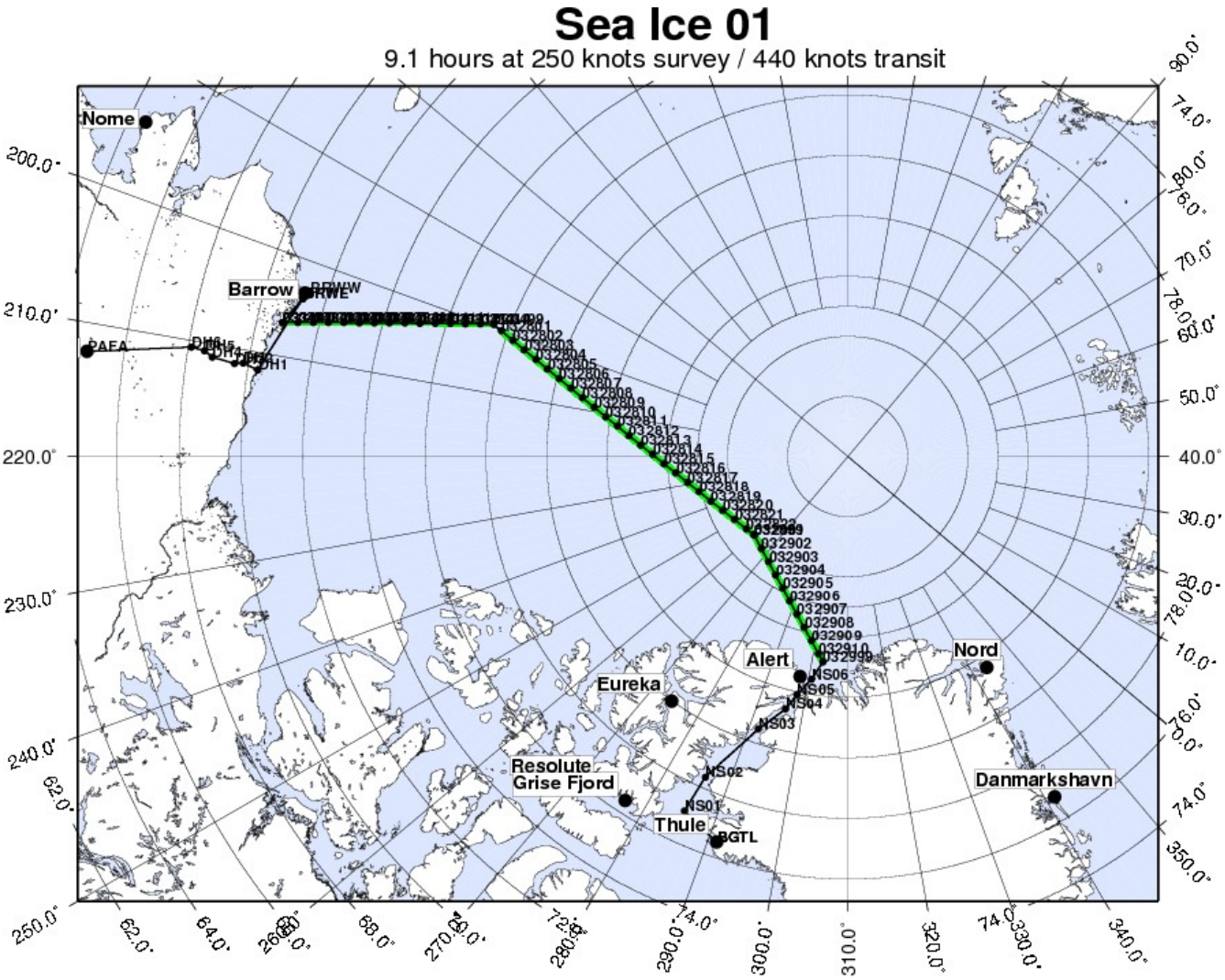


# Sea Ice 01 – DC-8 / Thule to Fairbanks

This mission is currently an exact repeat of the 090405 Arctic basin transect from Fairbanks to Thule, although in this case we plan to fly the mission in the reverse direction, from Thule to Fairbanks. Flying with the Sun, we also gain more time to conduct a simple out-and-back survey line near Point Barrow, which is closer to this flightline than the orginal 090402 Thule to Fairbanks flight. We also overfly the Dalton Highway between Prudhoe Bay and Atigun Pass (over the Brooks Range) on the leg from the northern Alaska coast to Fairbanks. Please call Larry Hinzman at UAF when you know this flight will be flown. He will coordinate the ground validation effort for permafrost and has also offered to help with anything else you may need in Fairbanks. LVIS should be on for transits.

**Flight Priority:** High **Instrument Priority:** ATM, Snow Radar, Gravimeter

**ICESat Track:** 0329, 0328,0334

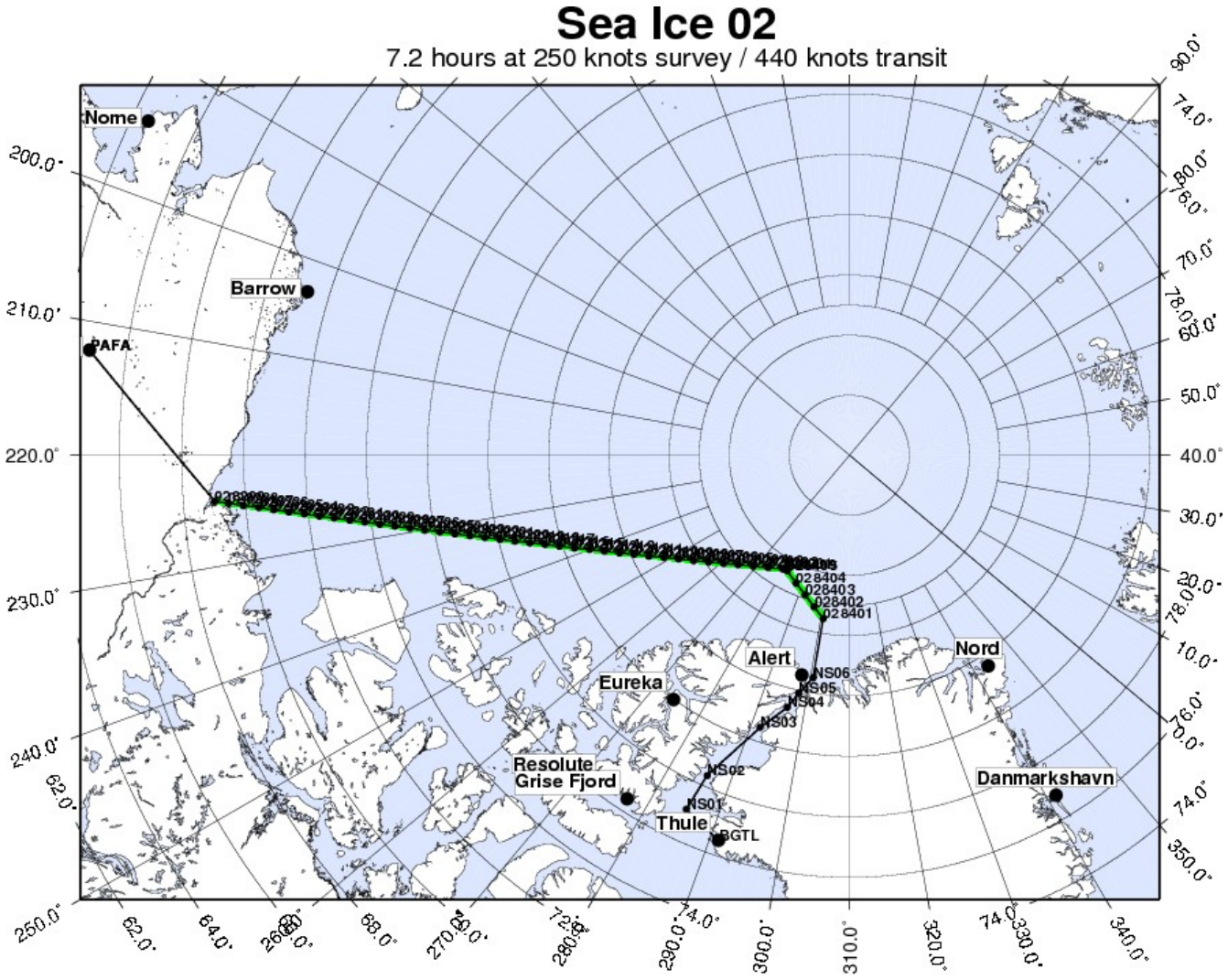


# Sea Ice 02 – DC-8 / Fairbanks to Thule

This mission is an exact repeat of the 090402 flight, though flown in the reverse direction for the reasons stated for mission Sea Ice 01. Timing on this flight is very tight because we need at least predawn twilight lighting conditions for VFR flight once off the northern Alaska coast, but also must land at Thule before the airfield closes at 1600 local time. Thus we should not add significant time to this particular mission. LVIS should be on for the transit out of Fairbanks over the permafrost region and Nares Straight.

**Flight Priority:** High **Instrument Priority:** ATM, Snow Radar, Gravimeter

**ICESat Track:** 0282,0284

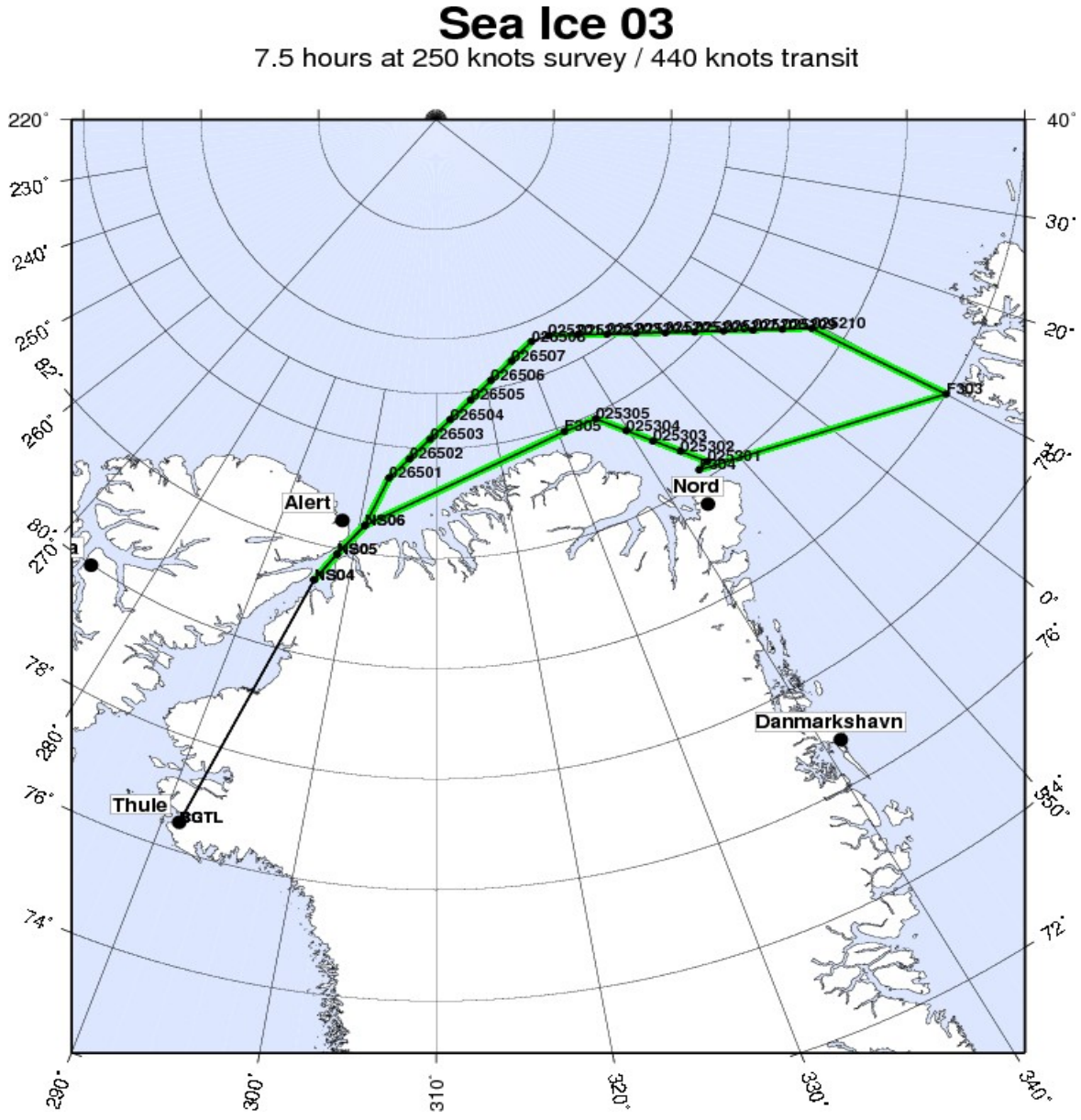


# Sea Ice 03 – DC-8 / Thule

This mission is very similar to the 090331 Fram Straight mission, but we add a low-altitude survey across the “ice arch” at the top of the Nares Straight.. LVIS should be on for transit through the Fram Straight.

**Flight Priority:** High **Instrument Priority:** ATM, Snow Radar, Gravimeter

**ICESat Track:** 265,252,253

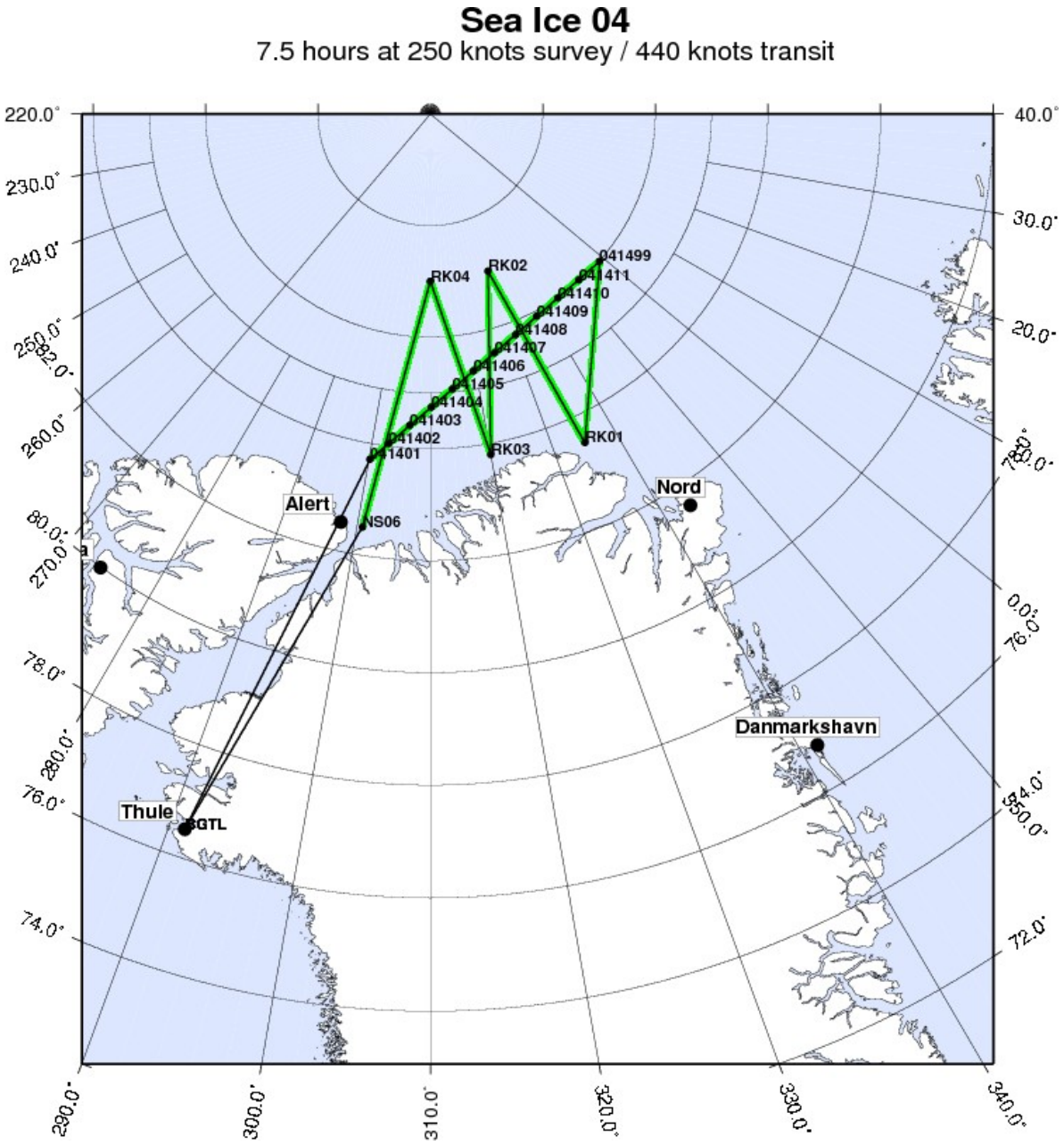


# Sea Ice 04 – DC-8 / Thule

This mission is very similar to the 2009 high-altitude LVIS sea ice flight, but this time we plan to fly at low altitude and utilize the ATM and snow radars primarily. It is intended to sample the thick multi-year ice near the Greenland coast as well as the gradient to thinner ice closer to the pole. It also samples ICESat track #0414. **LVIS on for transit.**

**Flight Priority:** Medium **Instrument Priority:** ATM, Snow Radar, Gravimeter

**ICESat Track:** 414



# Sea Ice 05 – DC-8 / Thule

This is a new mission, intended to sample thick multi-year ice immediately north of Ellesmere Island, and the gradient to thinner ice toward the pole. It also samples ICESat ground track #0195. LVIS on for transit.

**Flight Priority:** Medium **Instrument Priority:** ATM, Snow Radar, Gavimeter

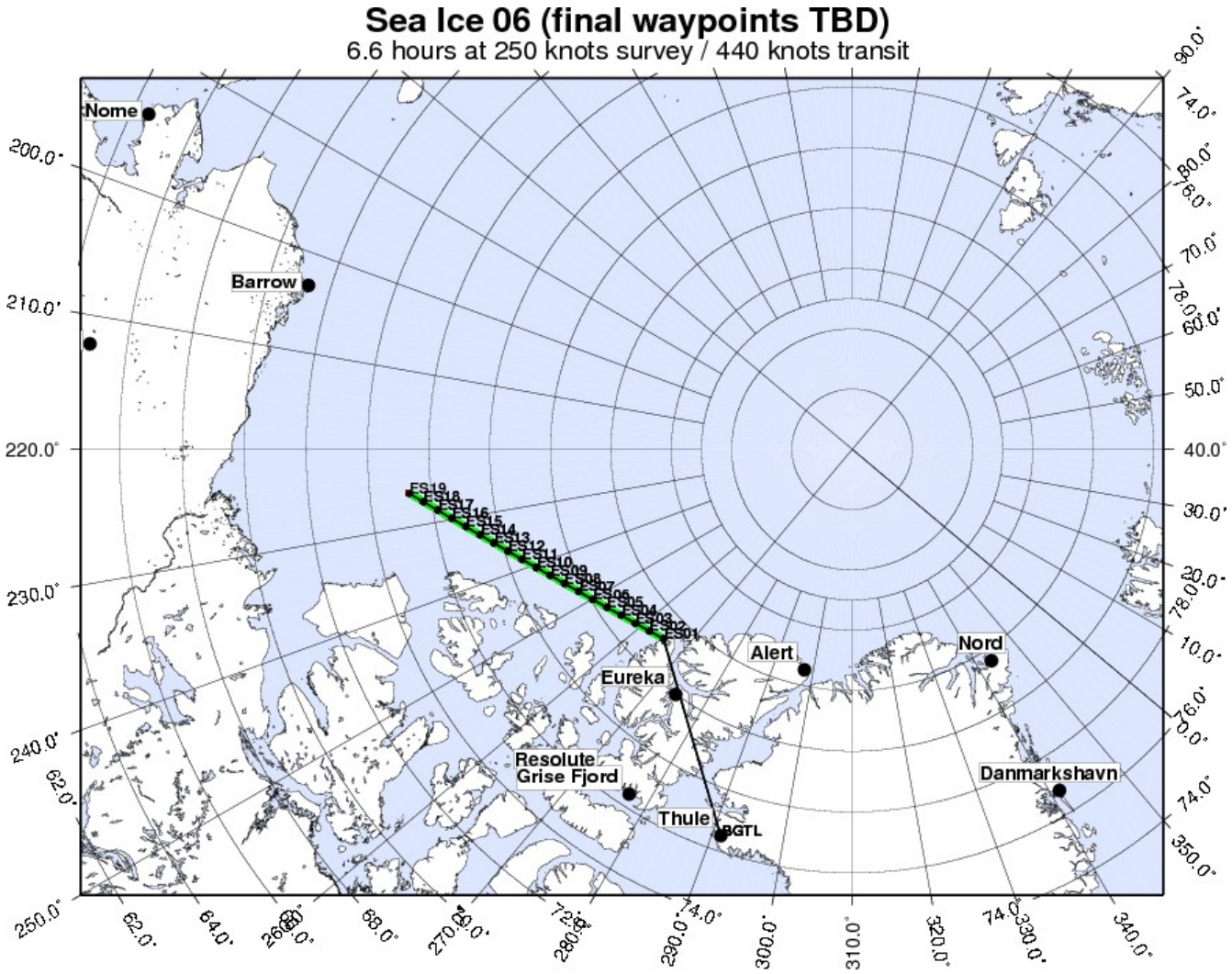
**ICESat Track:** 195

# Sea Ice 06 – DC-8 / Thule (or Fairbanks)

This mission is intended to sample along the Envisat ground track. As depicted here the mission is an exact repeat of the 2009 Envisat flight, but we will replan the waypoints to fly a time-coincident Envisat track with our ICEBridge mission. The objectives of this mission could also be fulfilled by flying a similar mission from Fairbanks, if that proved to operationally desirable. This flight is in collaboration with NOAA. Please call Dave McAdoo or Sinead Farrell with any questions. Because of orbital geometry, the best days to fly this mission are April 5th and April 6th. It should not be flown on March 25th or April 4th, for the same reasons. Other favorable days to fly it are 23 March, 24 March, 26 March, 27 March, 30 March, 2 April and 3 April, but 5 and 6 April are preferred.

**Flight Priority:** High **Instrument Priority:** ATM, Snow Radar, Gravimeter

**ICESat Track:** none, Envisat line

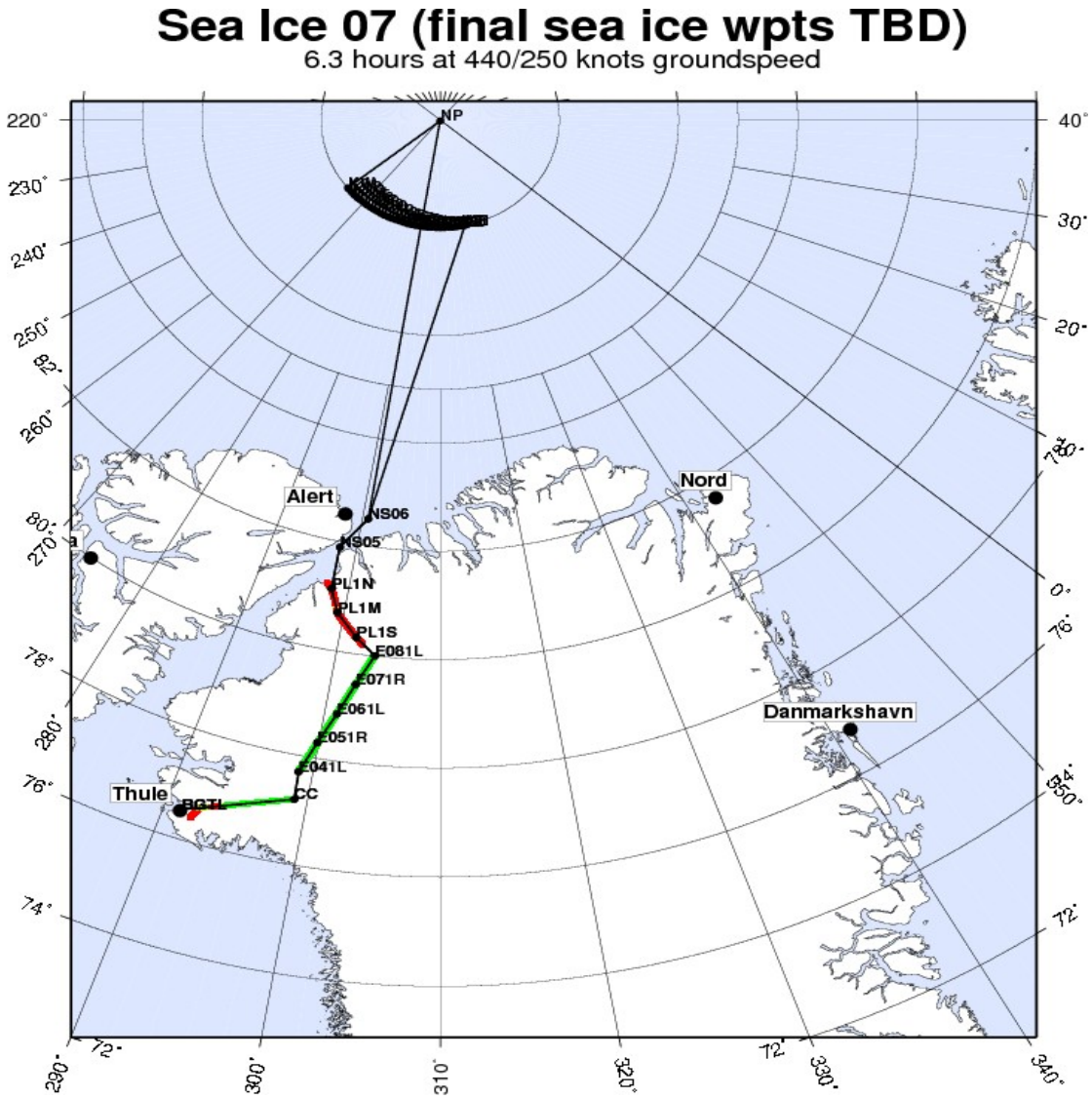


# Sea Ice 07 – DC-8 / Thule

This mission is a ATM/ LVIS calibration mission over the ice sheet and will additionally over fly a sea ice camp. This flight line allows LVIS and ATM to overfly a large portion (>100 km) of the ice sheet over multiple terrain types to allow for calibration between the two instruments. It also overflies areas where ATM has a long time series of data. During the LVIS portion of this flight the snow radar may not perform well (or at all) from the high-altitude but it will be turned on in an experiment since. This mission is a rough draft, and the exact waypoints over the sea ice will be based on the position of a field camp and will be provided by Ron Kwok. This flight should occur after April 10, 2010 to coincide with the field camp.

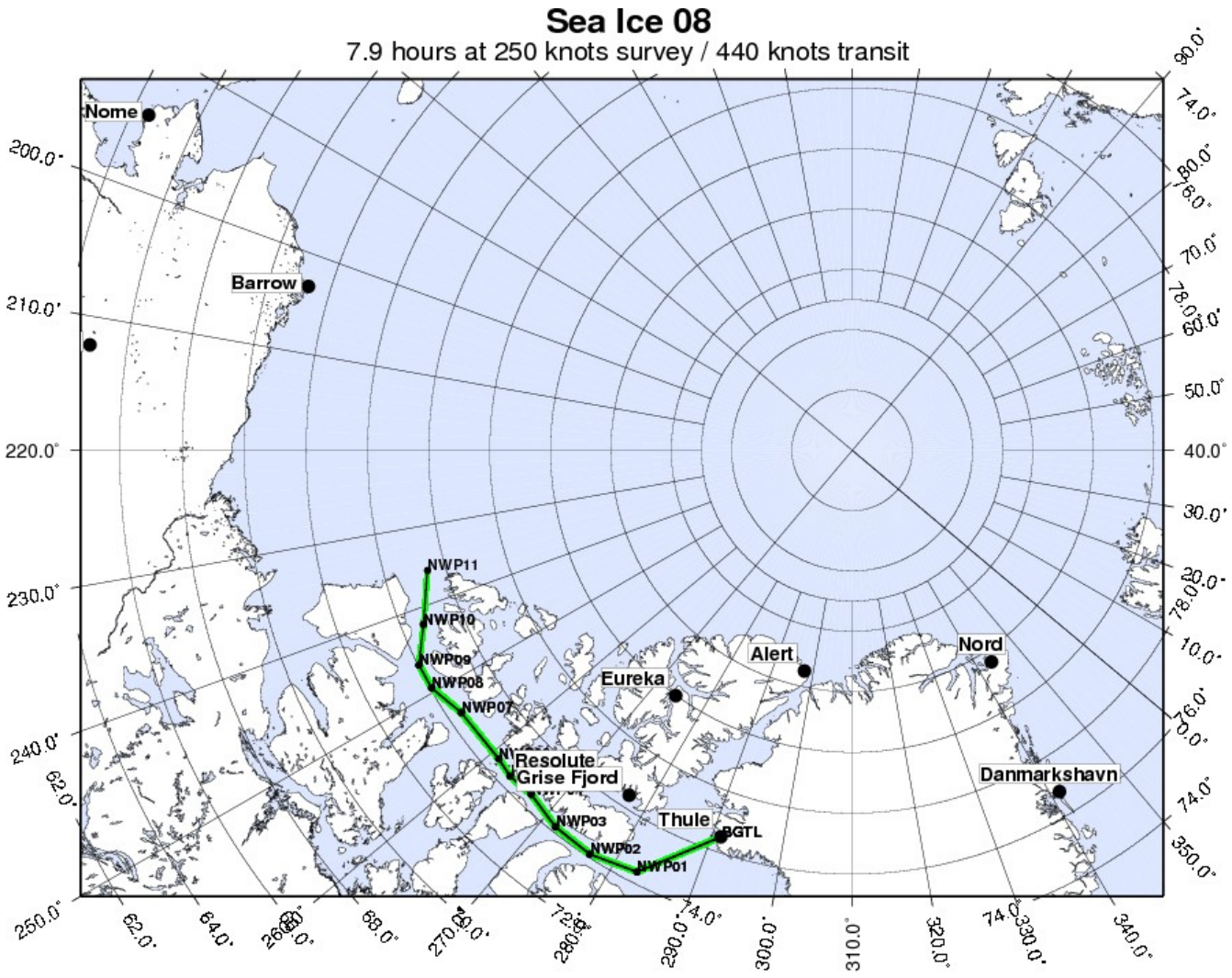
**Flight Priority:** High **Instrument Priority:** LVIS, ATM, Snow radar,Gravimeter

**ICESat Track:** none



# Sea Ice 08 – DC-8 / Thule

This mission is a new design, intended to fly along the northwest passage route.
**Flight Priority:** Medium **Instrument Priority:** ATM, Snow Radar, Gravimeter
**ICESat Track:** none

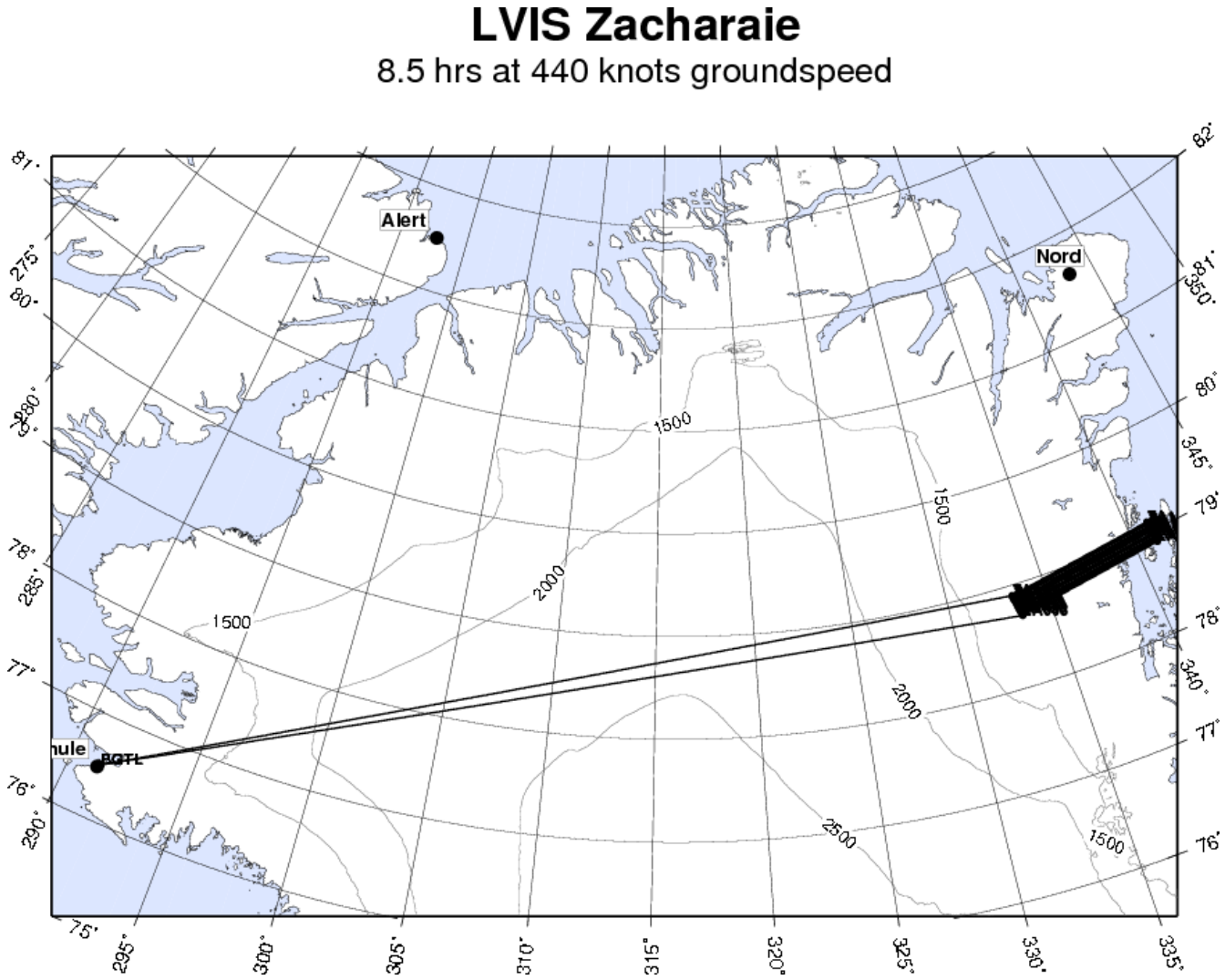


# LVIS Zacharaie – DC-8 / Thule

This mission is a new design, and its objective is high-altitude area mapping of the lower Zacharaie Glacier using the LVIS sensor. This will additionally be an experimental high altitude flight for the Kansas radar suite. The radar should be turned on to determine their abilities at LVIS altitudes and speeds.

**Flight Priority:** Low **Instrument Priority:** LVIS, MCoRDS for high altitude test

**ICESat Track:** Many short tracks

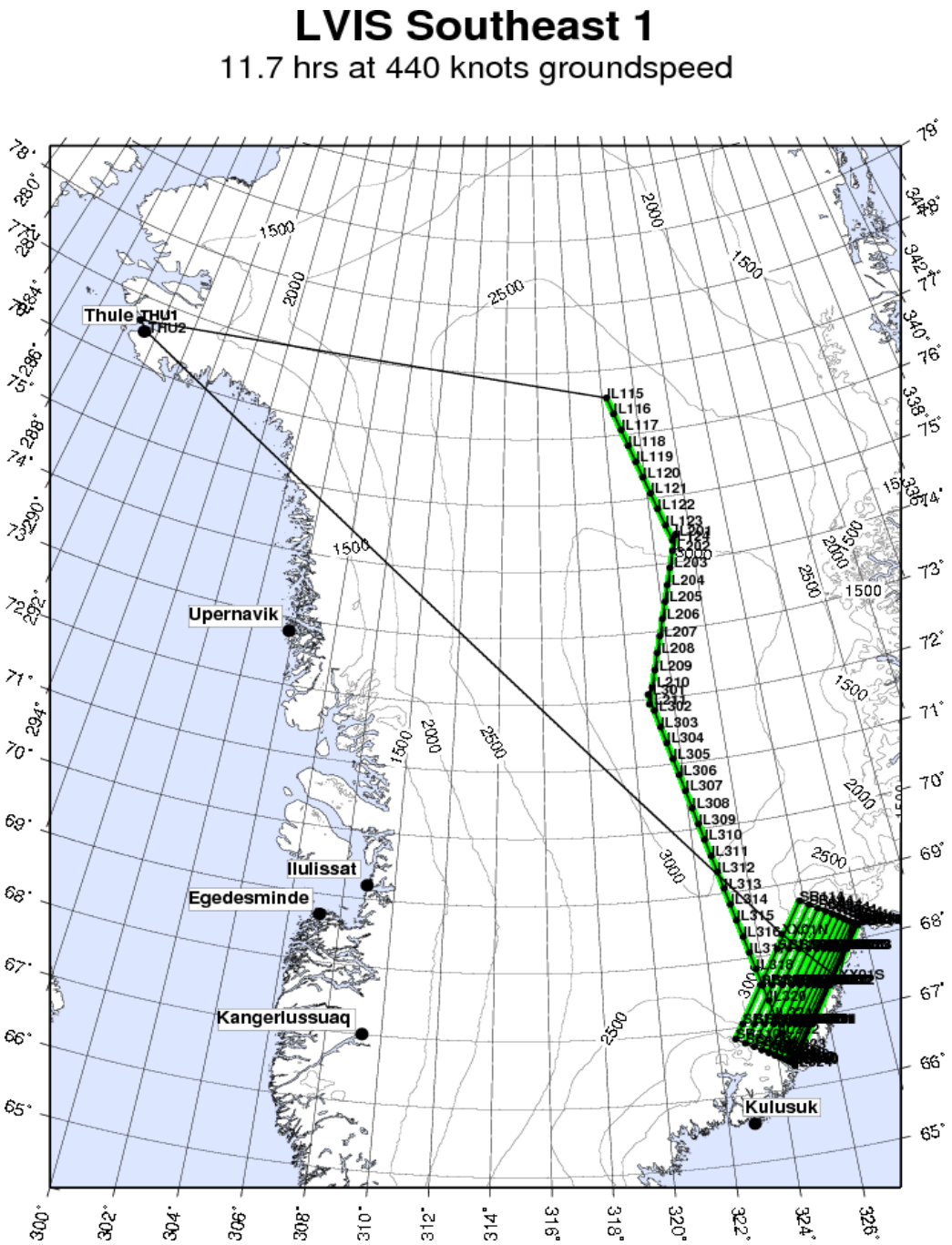


# LVIS Southeast – DC-8 / Thule

This mission is a new design, and its objective is high-altitude area mapping using the LVIS sensor. This mission is also an ICESat/LVIS calibration mission over ICESat track 0412 over Summit Camp, Greenland. Notify Bob Hawley and Summit Camp when this flight will occur so they can gather coincident ground truth data.

**Flight Priority:** High **Instrument Priority:** LVIS

**ICESat Track:** 412,91,359

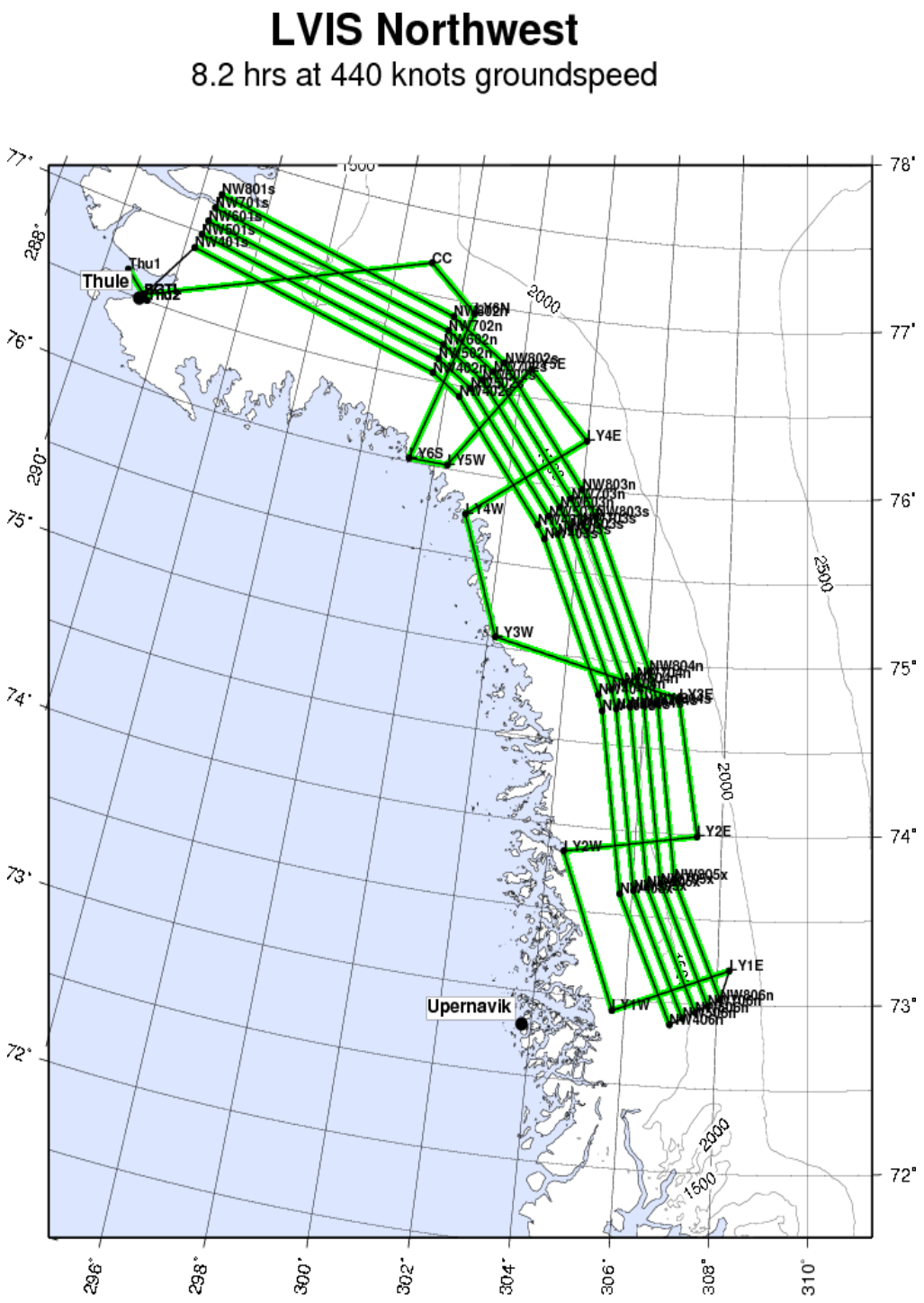


# LVIS Northwest – DC-8 / Thule

This mission is a new design, and it is designed to complement the "NWCoastal 01 and 02" P-3 missions, by extending the coast-parallel grid inland on a 10 km spacing. The mission also includes several crossovers of the lines.

**Flight Priority:** High **Instrument Priority:** LVIS

**ICESat Track:** Many short tracks

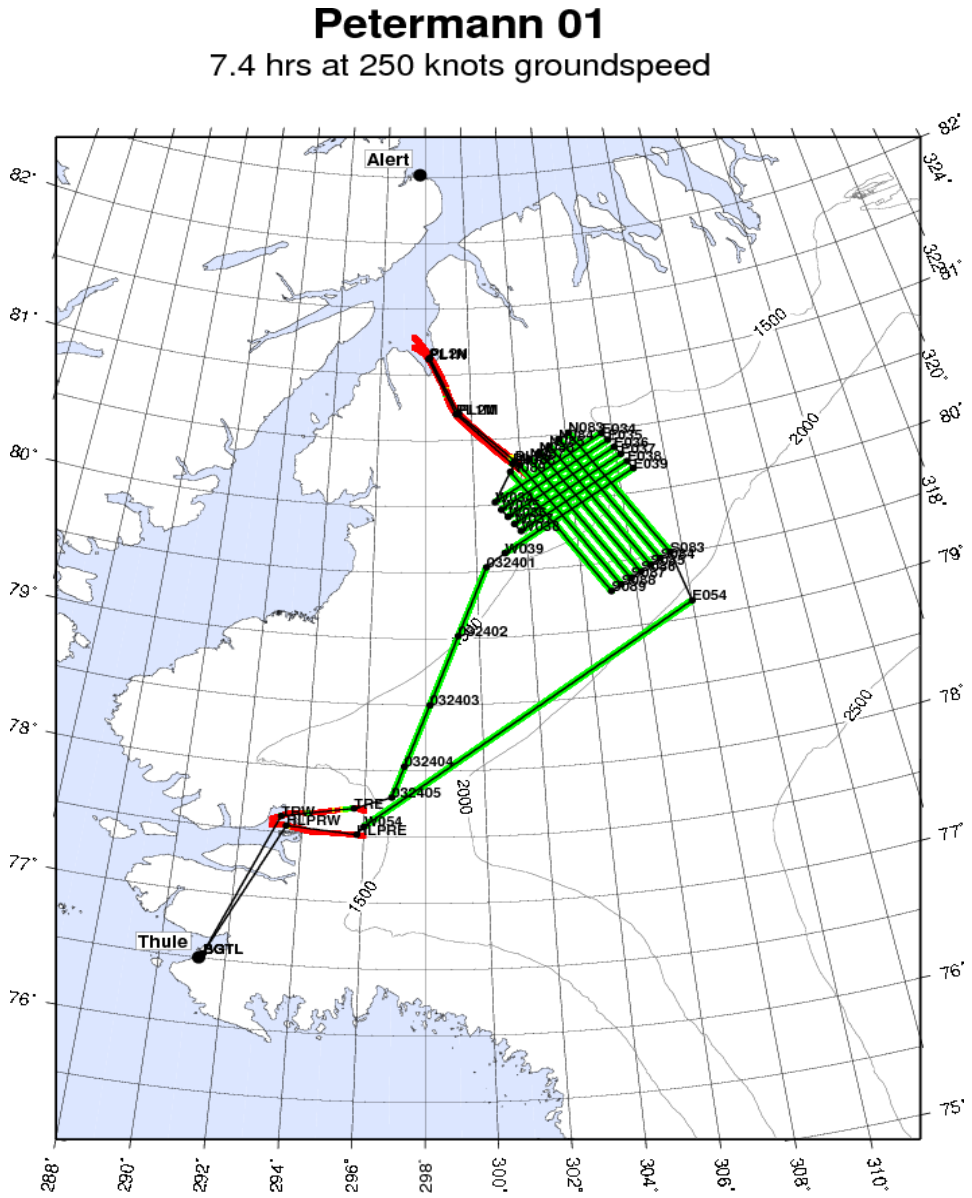


# Petermann 01 – DC-8 / Thule

This is mostly a new mission, designed primarily to map the bed of part of the upper catchment area of Petermann Glacier, using the 10-km north Greenland "master grid". This flight line is also designed to test the gravimeter over the Petermann ice shelf. The design supplements work done at Petermann in 2009 and prior years. The mission also continues dh/dt monitoring of Petermann Glacier by flying along parallel flowlines which have been flown previously. These lines have gentle curvature but the lateral accelerations may be small enough to permit accurate gravimetry measurements of the cavity beneath the ice shelf as well. Finally, we reoccupy lines first flown during the 2009 IceBridge deployment over two small glaciers north of Thule, known as Heilprin and Tracy Glaciers

**Flight Priority:** Medium **Instrument Priority:** MCoRDS, ATM, Gravity

**ICESat Track:** 324

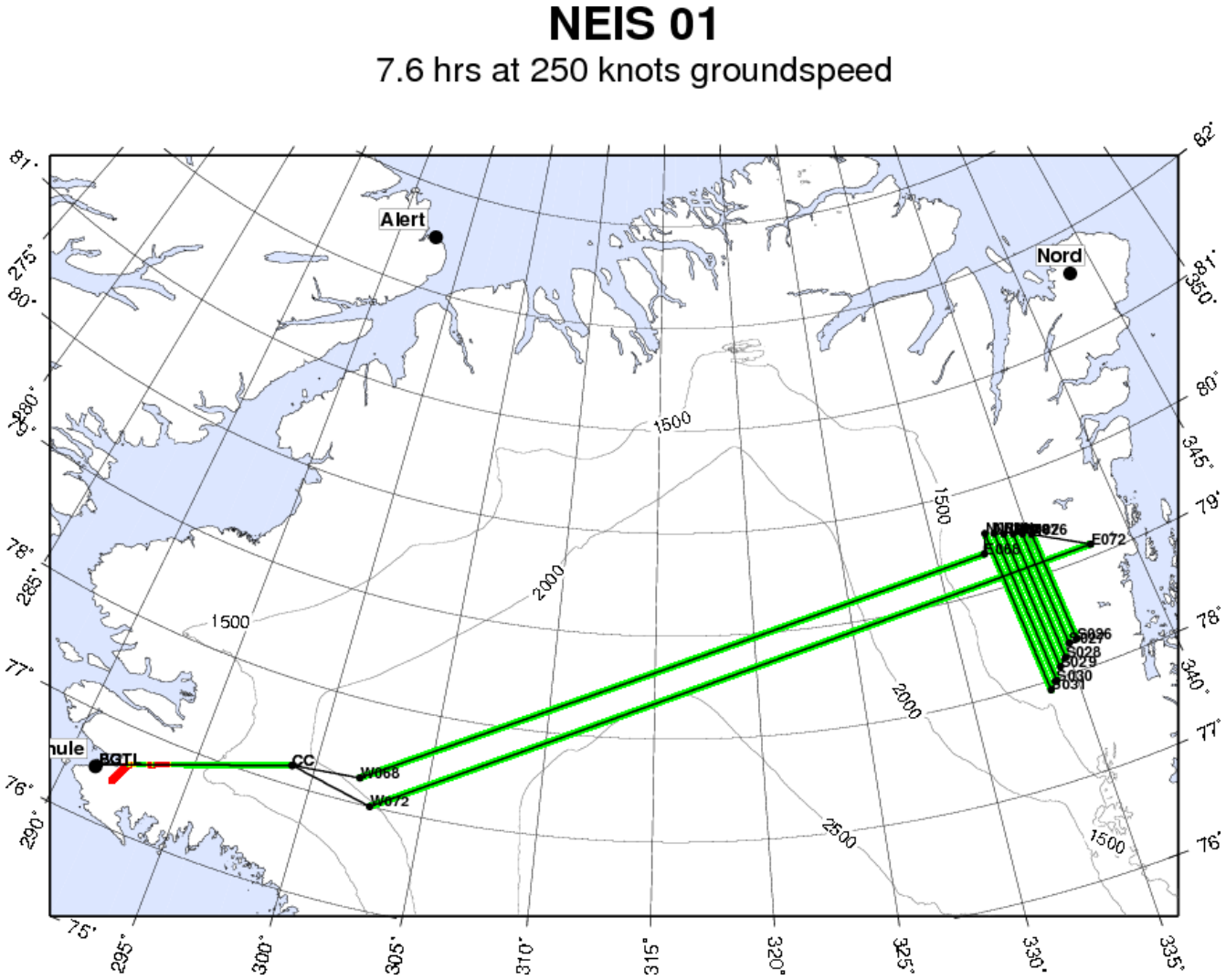


# NEIS 01 – DC-8 / Thule

This is a new mission, designed as part of a 4-mission sequence to map a 10 km grid pattern on the Zacharaie Glacier and lower Northeast Ice Stream. Two missions are planned for the DC-8 to map the interior portion of this grid, and two additional for the P-3 to map the lower part of the grid over Zacharaie Glacier. This is the first of the DC-8 missions. We also re-occupy the Camp Century Corridor and two of the 10 km master grid EW lines.

**Flight Priority:** Medium **Instrument Priority:** MCoRDS, ATM

**ICESat Track:** none

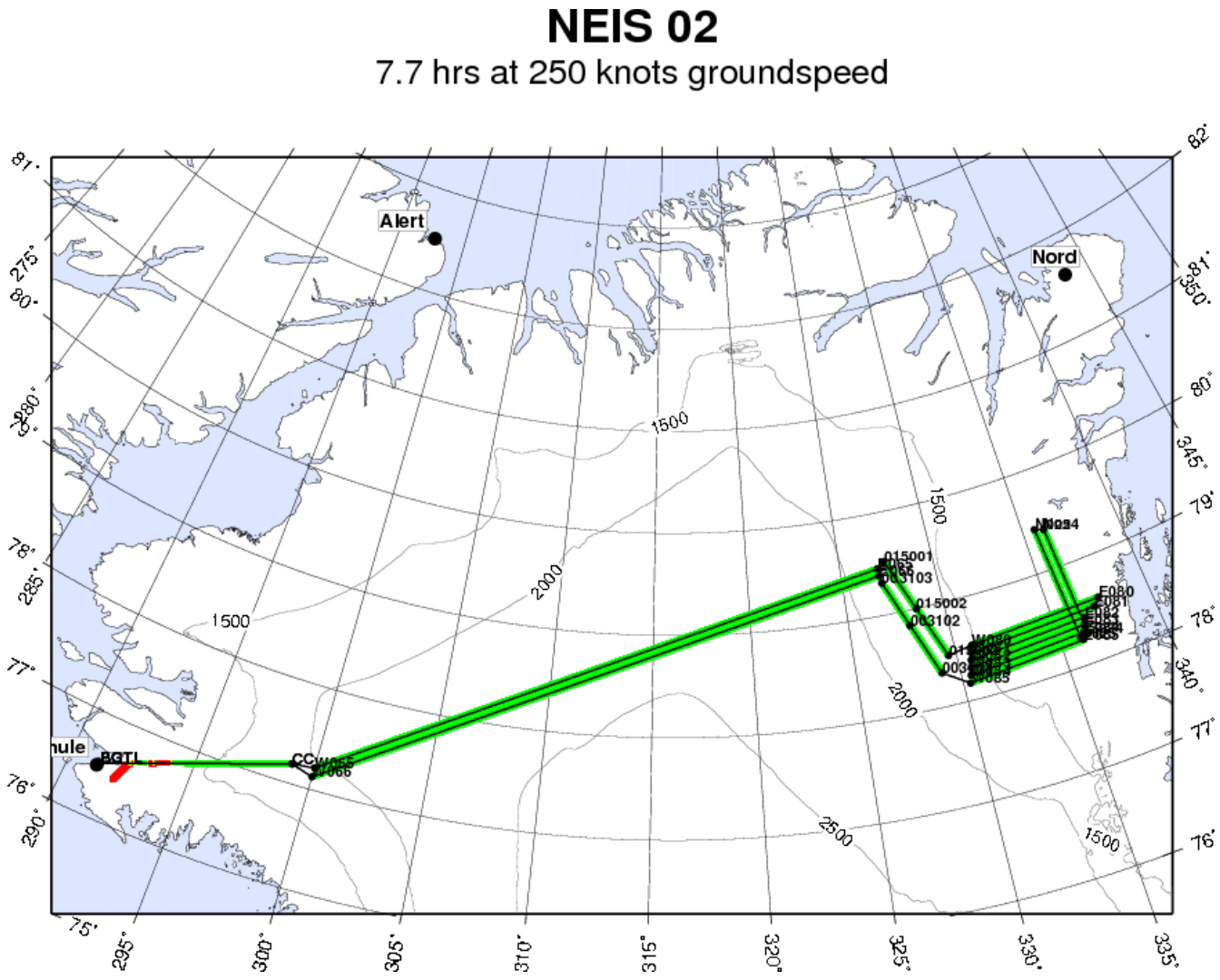


# NEIS 02 – DC-8 / Thule

This is a new mission, designed as part of a 4-mission sequence to map a 10 km grid pattern on the Zacharaie Glacier and lower Northeast Ice Stream. Two missions are planned for the DC-8 to map the interior portion of this grid, and two additional for the P-3 to map the lower part of the grid over Zacharaie Glacier. This is the second of the DC-8 missions. We also reoccupy the Camp Century Corridor and two of the east-west 10 km master grid lines, as well as two small segment of ICESat ground tracks.

**Flight Priority:** Medium **Instrument Priority:** MCoRDS, ATM

**ICESat Track:** 0150,0031

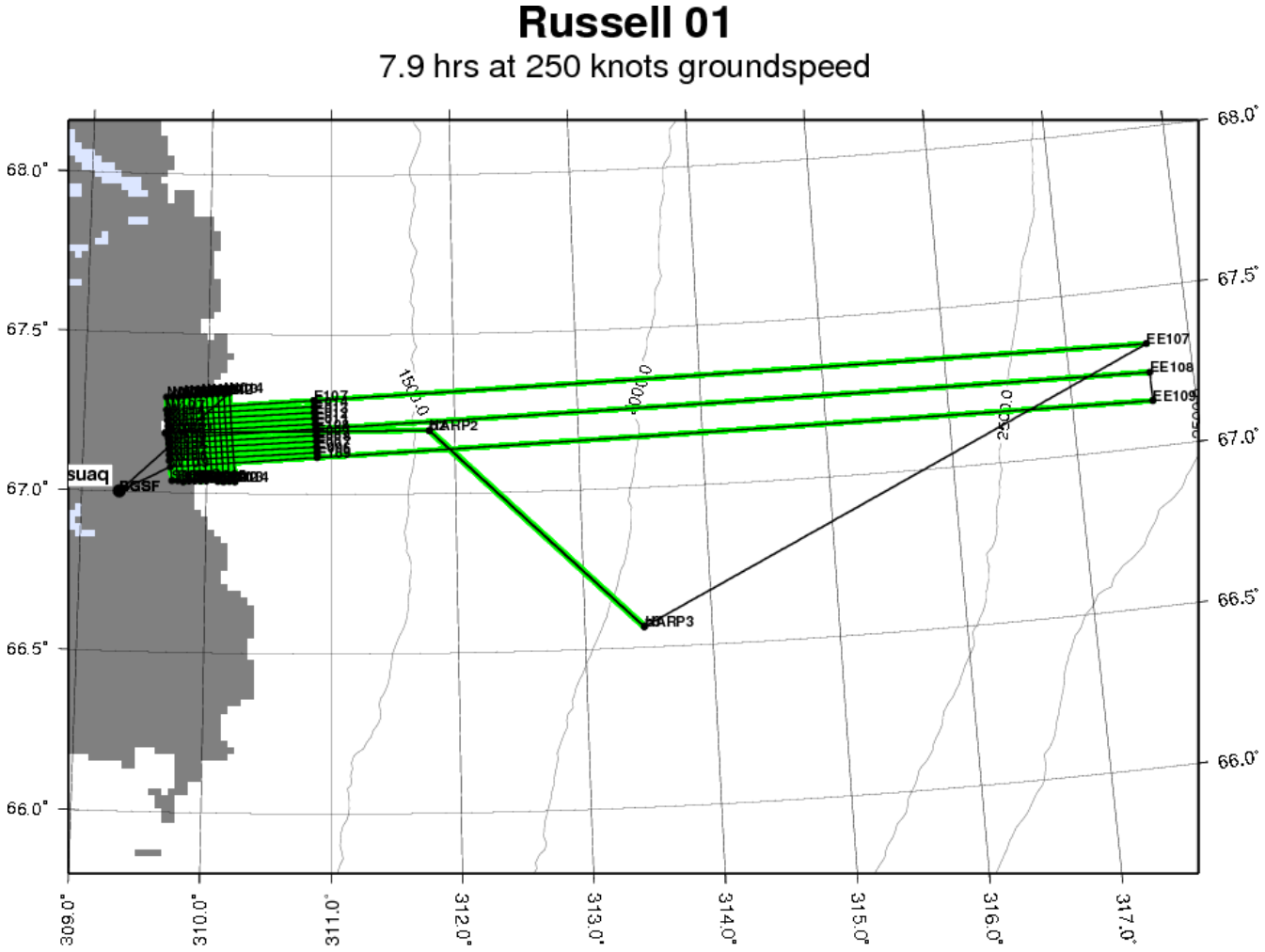


# Russell 01 – P-3 / Kangerlussuaq

This is a new mission, designed to provide a very detailed bedrock map of the Russell and Isumanguata Sermia Glaciers, which are neighboring land-terminating glaciers and which lie very close to Kangerlussuaq. The grid is spaced at 2 km and is framed around the southern Greenland "master grid" of 10 km. Joel Harper will be taking borehole measurements in the area, and this plan includes a transect of the borehole sites as well as the grid.

**Flight Priority:** High **Instrument Priority:** MCoRDS, ATM

**ICESat Track:** none

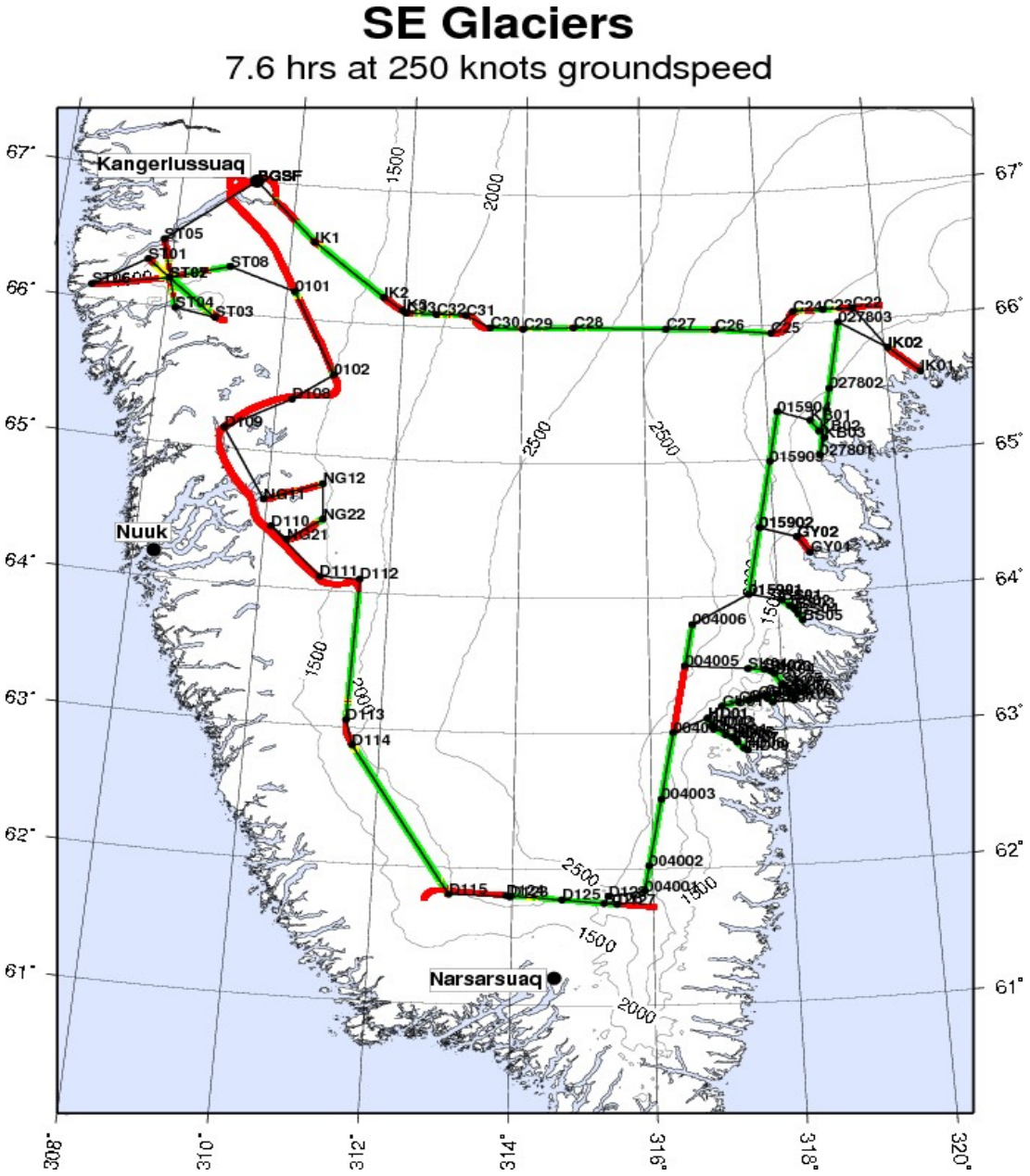


# SE Glaciers – P-3 / Kangerlussuaq

This mission is identical to a 2009 ICEBridge mission, plus the addition of a reflight of historic ATM lines over Sukkertoppen ice cap, just southwest of Kangerlussuaq. Its primary objective is to continue dh/dt monitoring of 12 glaciers, four in the southwest and eight in the southeast, using longitudinal flightlines down the approximate centerlines of each glacier. This flight line will also overfly the Southeast Greenland field traverse. Please contact Rick Forster or Polar field services so coincident ground truth data can be gathered.

**Flight Priority:** High **Instrument Priority:** ATM, MCoRDS, Gravity

**ICESat Track:** 159, 040, 010

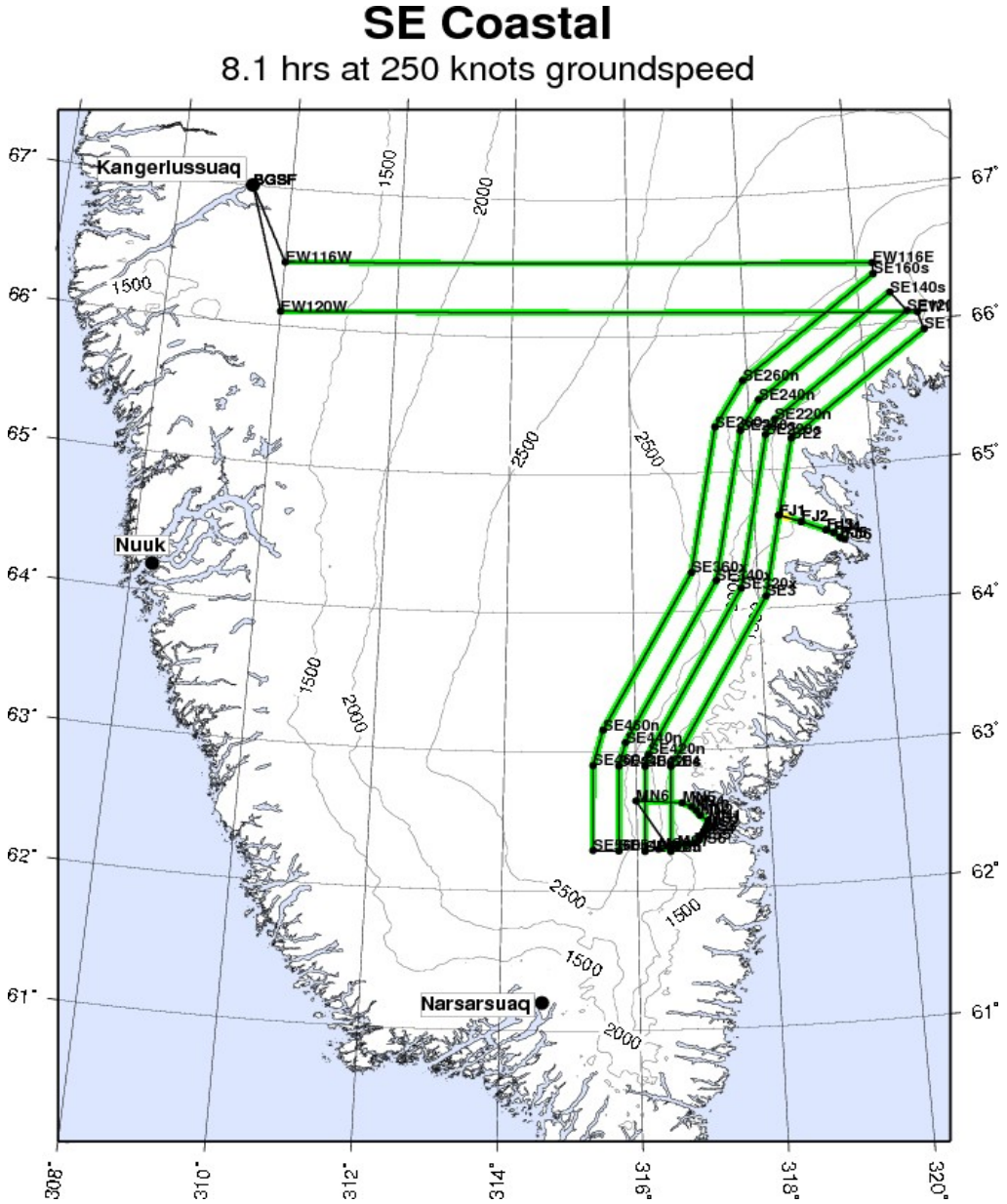


# SE Coastal – P-3 / Kangerlussuaq

This is a new mission, designed to map the lower flank of southeastern Greenland coast with a combination of all low-altitude sensors. The coast-parallel lines are separated by 20 km. We also map, for the first time, two glaciers at the head of Mogens Fjord and Fridtjof Glacier. See the "Supplementary Information" section for a map which shows how this mission relates to the "SE Glaciers" mission.

**Flight Priority:** High **Instrument Priority:** MCoRDS, ATM, Gravity

**ICESat Track:** none



# Helheim-Kangerdlugssuaq – P-3 / Kangerlussuaq

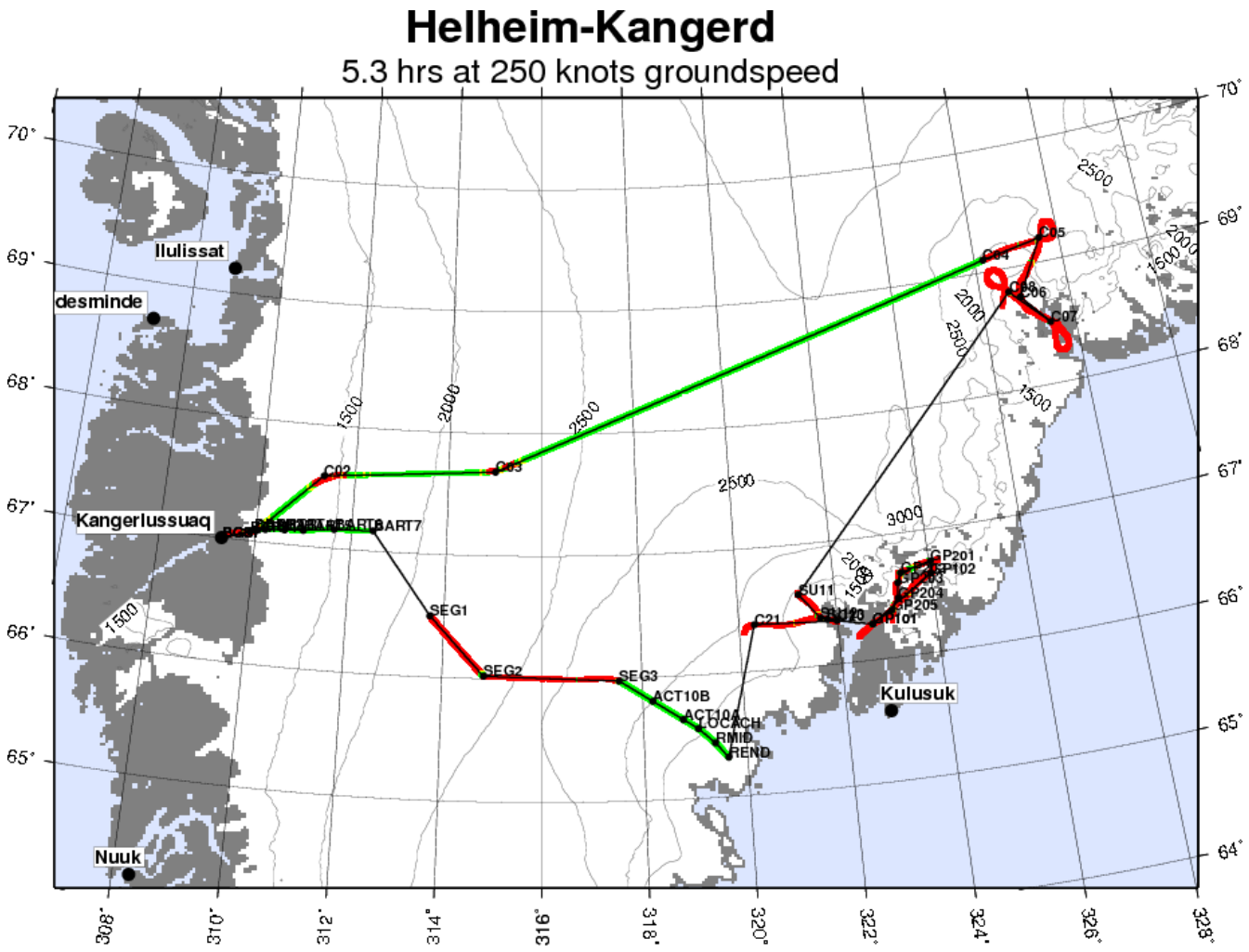
This mission is currently not fully fleshed-out. As shown here it includes flights along the historical ATM/CRESIS lines at Helheim, Midgard and Kangerdlugssuaq Glaciers for dh/dt monitoring of those glaciers. It also includes a flight along the route of the planned Forster southeast Greenland traverse, and along a GPS/traverse line near Kangerdlugssuaq established by Ian Bartholomew of the University of Edinburgh. According to the outcome of science planning meetings and other discussions, we also plan to add the following to this mission:

1. a number of cross-flow lines on upper Helheim and Kangerdlugssuaq, above the CRESIS 2009 grid, for radar bed mapping
2. cross-flow lines low on these two glaciers, for gravimetry

The exact placement of these lines will depend on the outcome of an ongoing analysis by CRESIS of their 2009 dataset collected over these two glaciers. This analysis is expected to be complete by late April.

**Flight Priority:** Medium **Instrument Priority:** ATM, MCoRDS, Gravity

**ICESat Track:** none

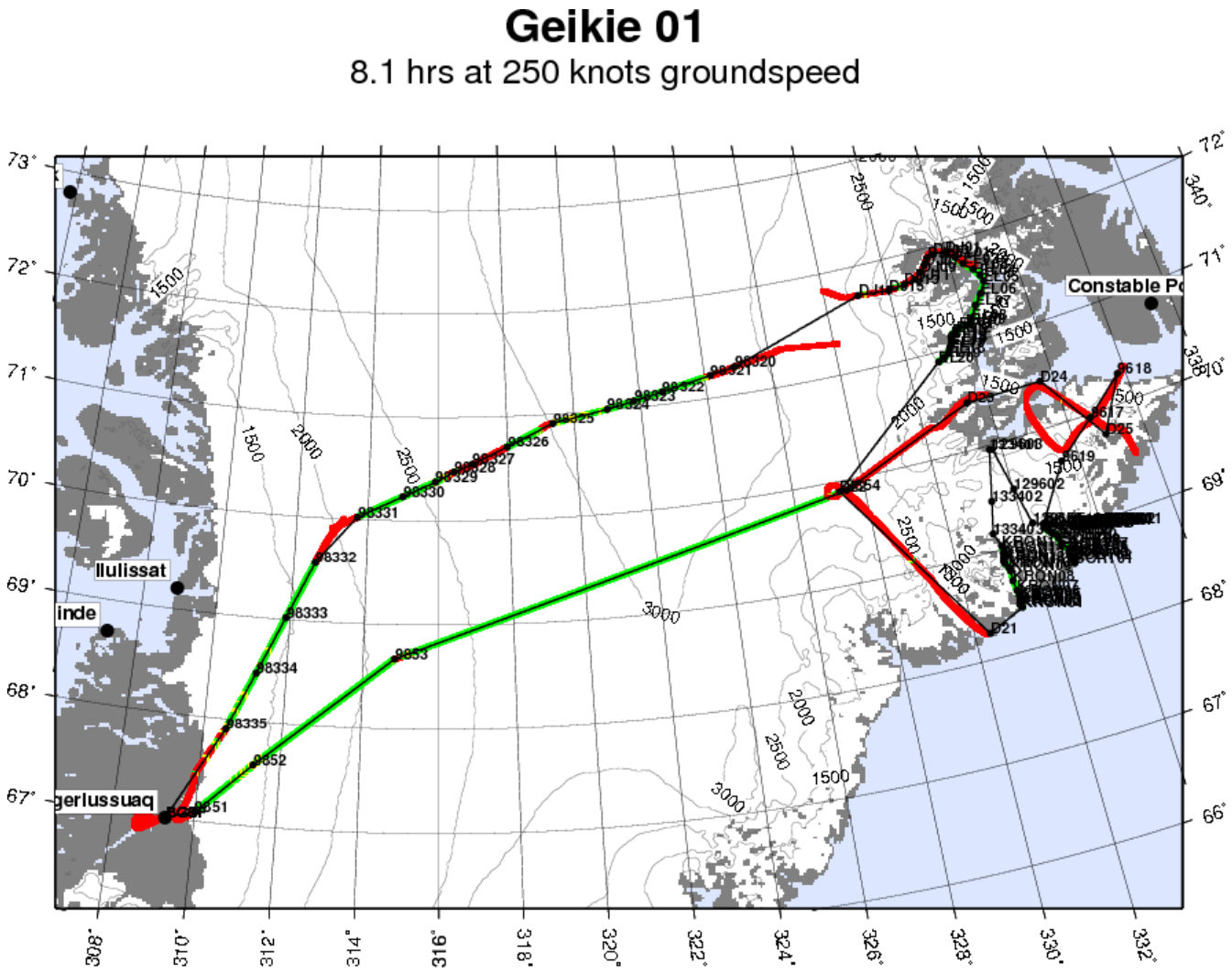


# Geikie 01 – P-3 / Kangerlussuaq

This is a new mission design, which incorporates many segments of old ATM/Kansas lines. We include reflights of lines along the Daugard-Jensen, Vestfjord and Kong Christian IV glaciers, and the "X" pattern over the Geikie Plateau. We also include new lines along the Eielson, De Reste Bugt, Sortebrae and Kronborg Glaciers. Old ATM lines across central Greenland are used to transit to and from Kangerlussuaq.

**Flight Priority:** High **Instrument Priority:** ATM, MCoRDS, Gravity

**ICESat Track:** 1334, 1296

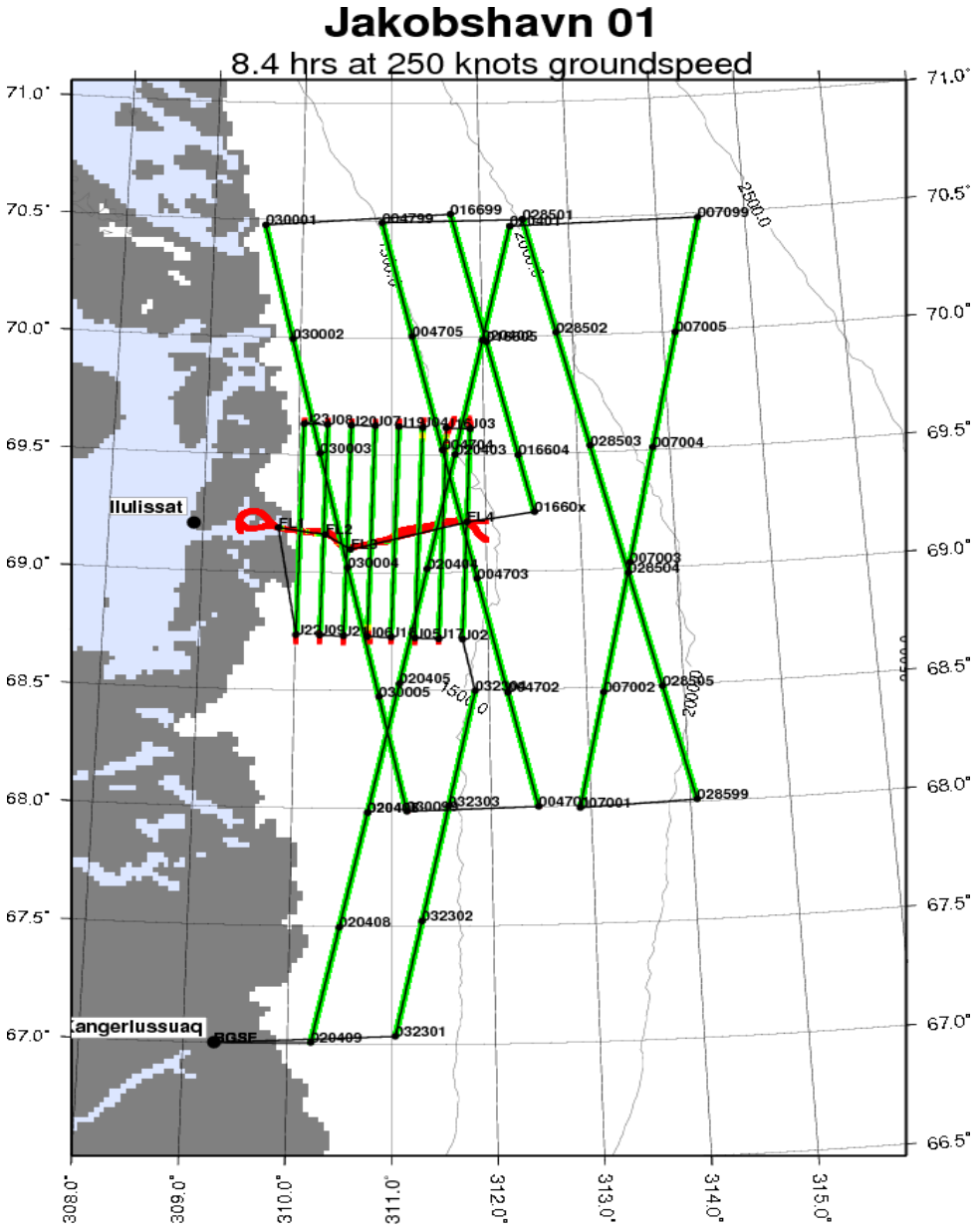


# Jakobshavn 01 – P-3 / Kangerlussuaq

This mission is very similar to a 2009 ICEBridge mission. The objective is to map the north-south lines of the ATM-established basic Jakobshavn grid, and to supplement this intensive grid with a much larger grid based on ICESat ground tracks. The intention of the latter part is to capture inland spread of the thinning which started on the lower Jakobshavn trunk and which has, in recent years, spread beyond the basic grid. We also occupy an approximation to the Jakobshavn flowline, which has been monitored by ATM for almost two decades.

**Flight Priority:** High **Instrument Priority:** ATM, MCoRDS, Gravity

**ICESat Track:** 0300,0047,0166,0070, 0204,0285, 0323

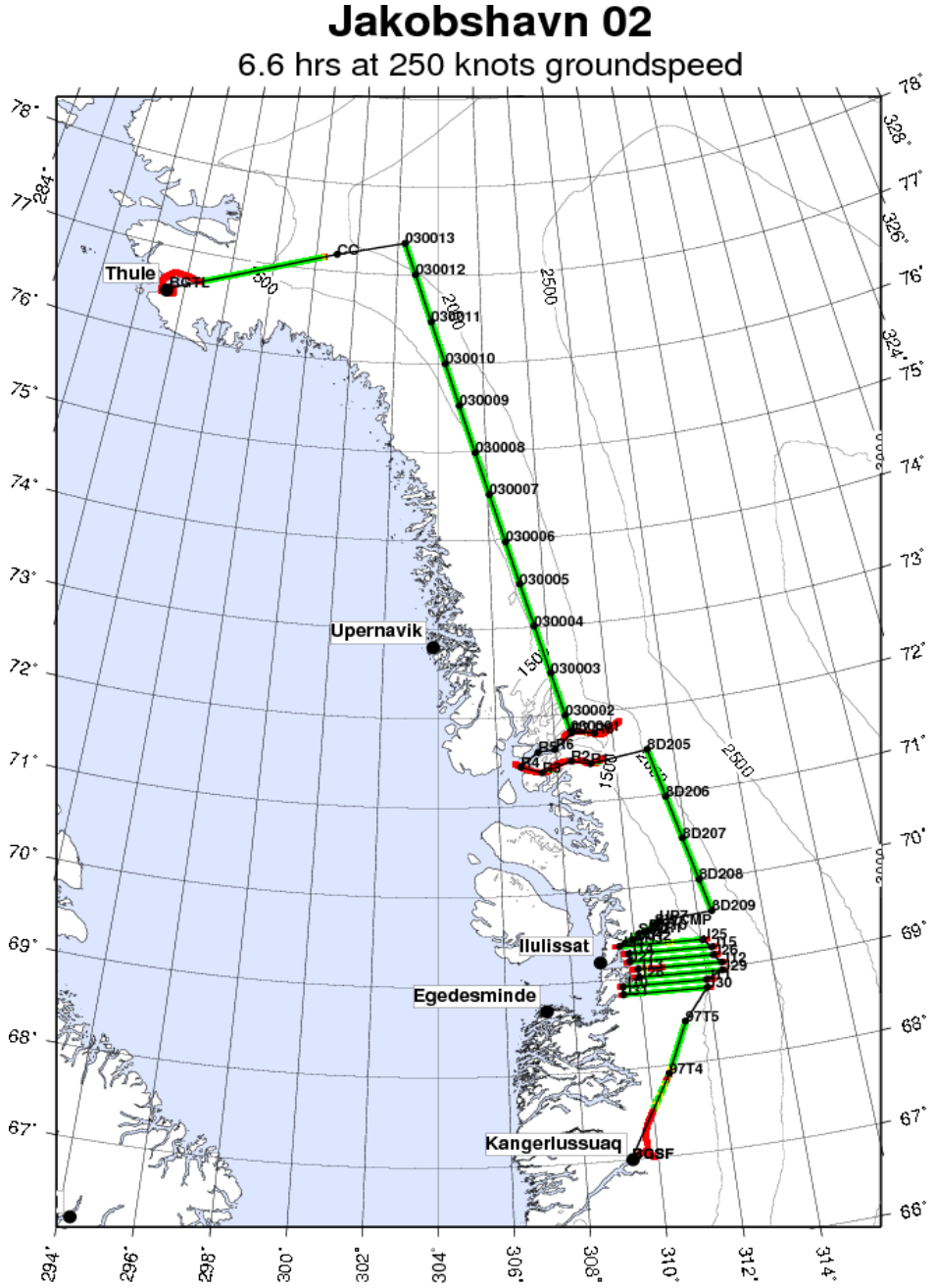


# Jakobshavn 02 – P-3 / Kangerlussuaq to Thule

This mission is similar to a 2009 ICEBridge flight. The primary science objectives are to (a) complete the basic Jakobshavn grid, specifically the east-west lines, (b) repeat longitudinal surveys of the Rink and Kangerdlugssup Glaciers, and (c) occupy a number if ICESat ground tracks. It also serves to reposition the P-3 from Kangerlussuaq to Thule. In response to specific requests from the science community, we also fly the JAR-AWS-Swiss Camp line and ICESat track #0300.

**Flight Priority:** Low **Instrument Priority:** ATM, MCoRDS, Gravity

**ICESat Track:** 300

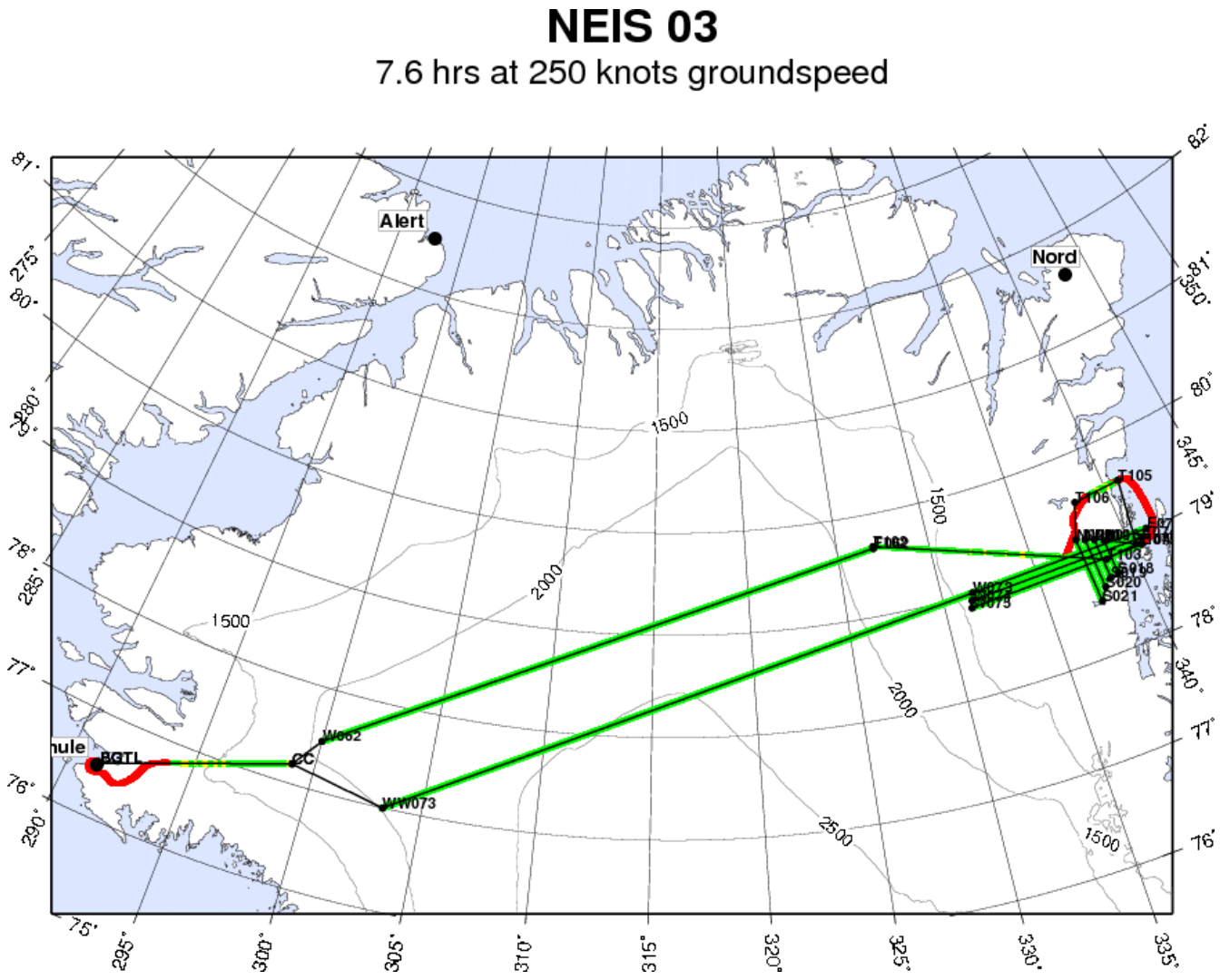


# NEIS 03 – P-3 / Thule

This is a new mission, designed as part of a 4-mission sequence to map a 10 km grid pattern on the Zacharaie Glacier and lower Northeast Ice Stream. Two missions are planned for the DC-8 to map the interior portion of this grid, and two additional for the P-3 to map the lower part of the grid over Zacharaie Glacier. This is the first of the P-3 missions. In addition to the 10 km grid work, this particular mission also occupies the historical ATM survey line down the centerlines of Zacharaie and 79N Glaciers, to continue dh/dt monitoring.

**Flight Priority:** Medium **Instrument Priority:** MCoRDS, ATM, Gravity

**ICESat Track:** none

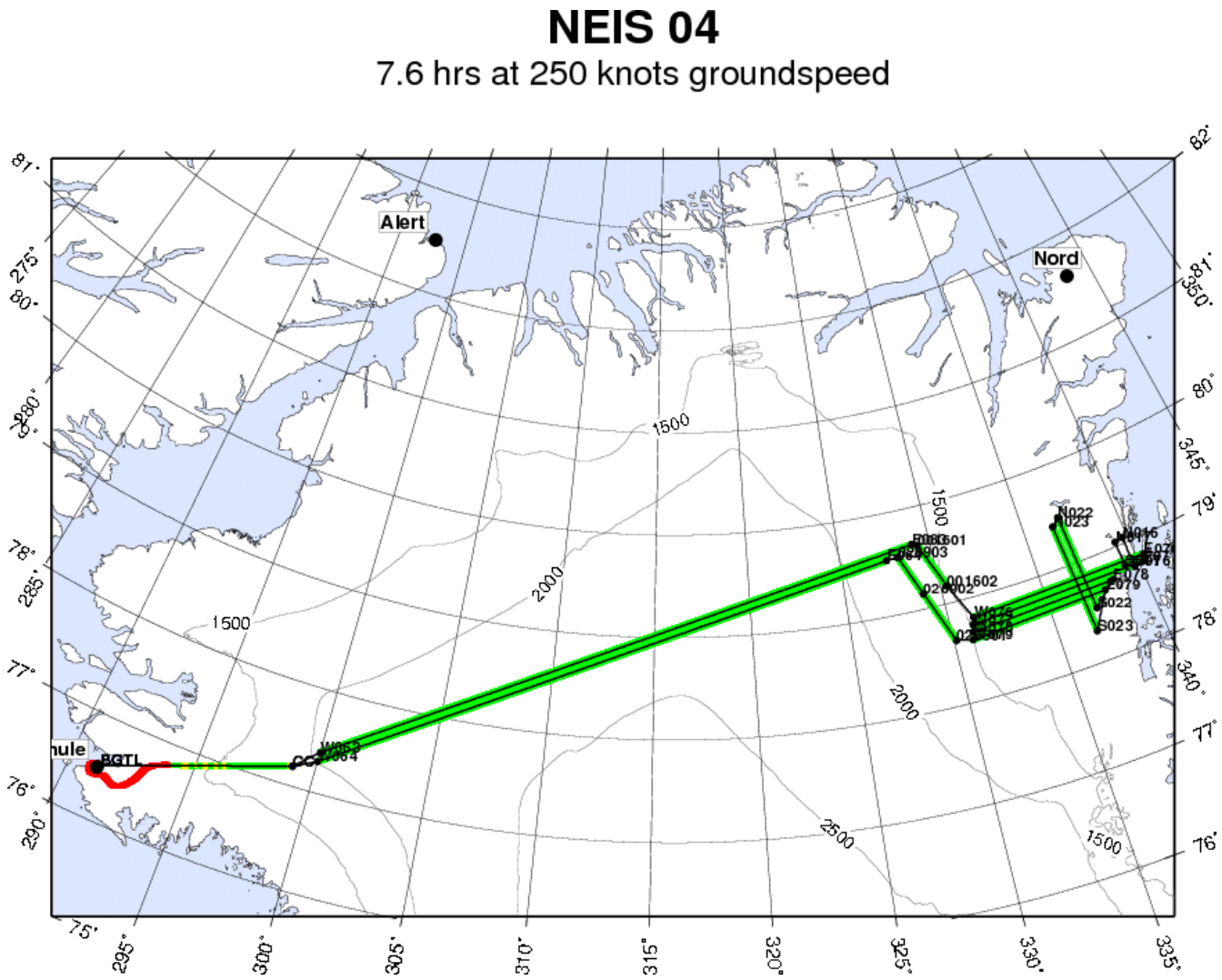


# NEIS 04 – P-3 / Thule

This is a new mission, designed as part of a 4-mission sequence to map a 10 km grid pattern on the Zacharaie Glacier and lower Northeast Ice Stream. Two missions are planned for the DC-8 to map the interior portion of this grid, and two additional for the P-3 to map the lower part of the grid over Zacharaie Glacier. This is the second of the P-3 missions.

**Flight Priority:** Medium **Instrument Priority:** MCoRDS, ATM, Gravity

**ICESat Track:** none

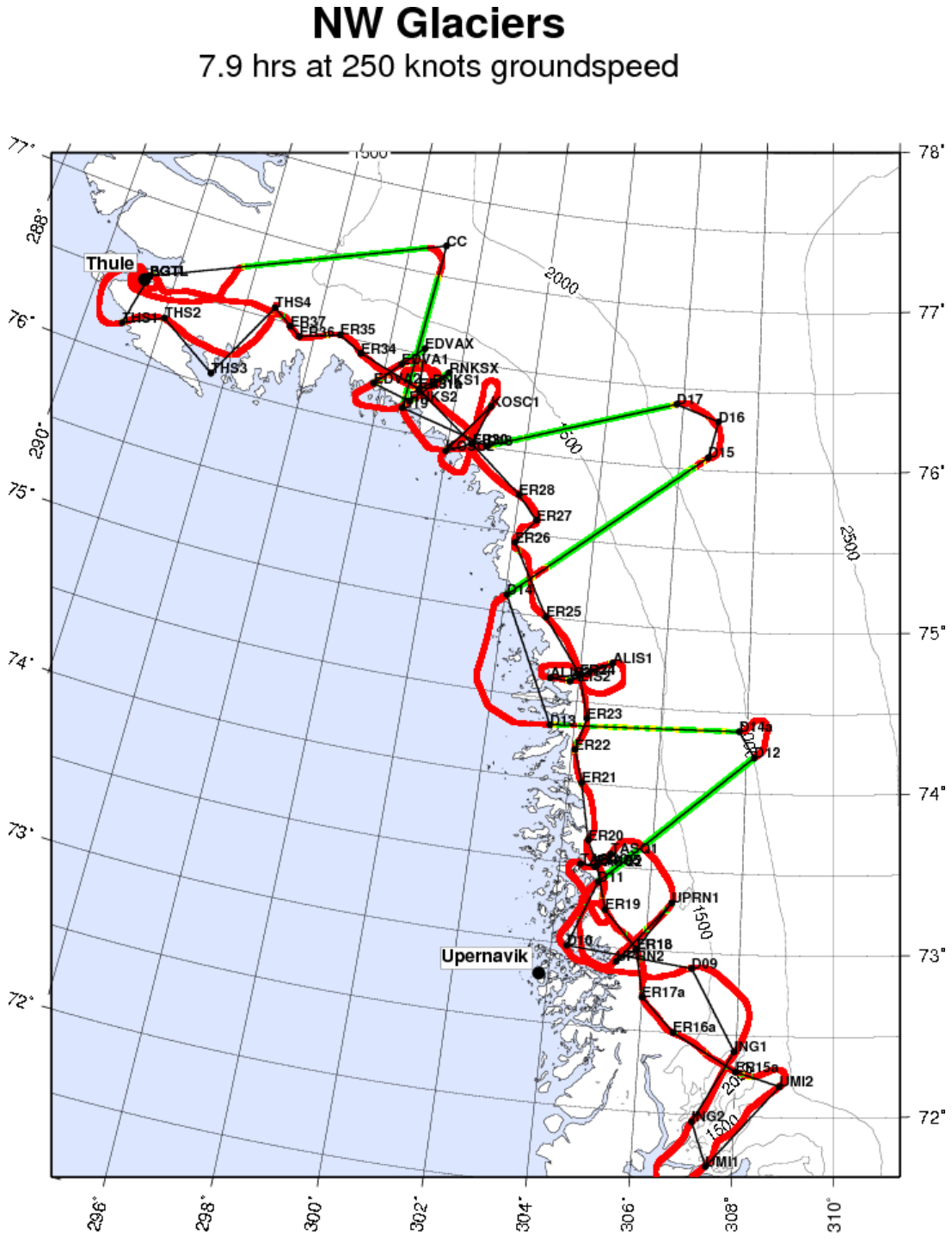


# NW Glaciers – P-3 / Thule

This mission is a repeat of a 2009 ICEBridge mission. It focuses on the upper Baffin Bay coast, with targeted longitudinal surveys of 12 glaciers in the region and repeats of long-established ATM dh/dt lines which were not targeted at outlet glaciers. For most of the outlet glaciers, this mission will be the first lidar repeat survey, and hence the first chance to measure high-precision dh/dt.

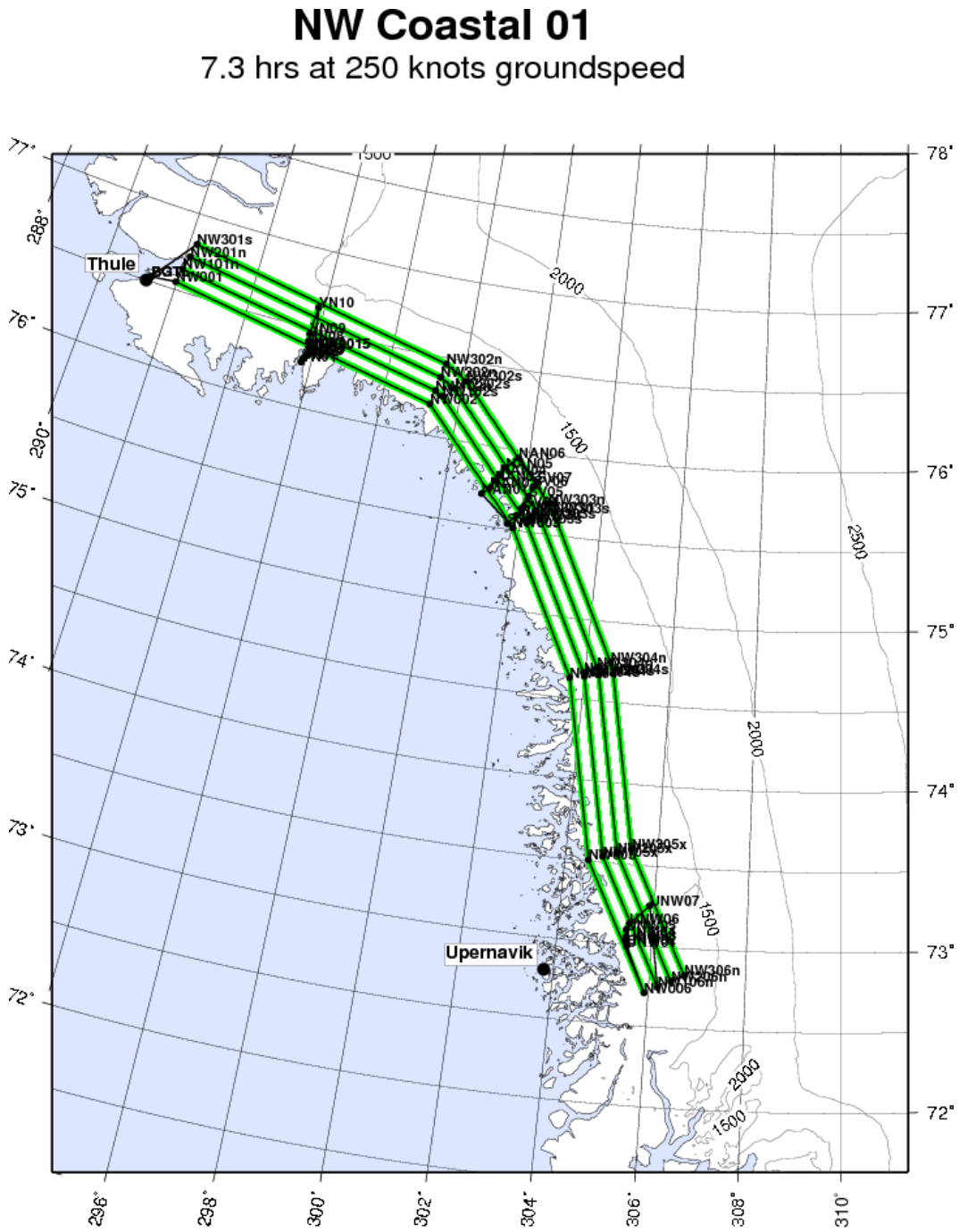
**Flight Priority:** High **Instrument Priority:** ATM, MCoRDS Gravity

**ICESat Track:** none



# NW Coastal 01 – P-3 / Thule

This is a new mission, designed to map the near-coastal area of the upper Baffin Bay coast with a combination of all low-altitude sensors. The coast-parallel lines are separated by 10 km. We also add new lines down the Nansen, Sverdrup, Yngvar Nielsen and Upernavik Northwest Glaciers. See the "Supplementary Information" section for a map which shows how this mission relates to the "NW Glaciers" and "NW Coastal 02" missions.
**Flight Priority:** High(to get 1 or 2) **Instrument Priority:** MCoRDS, ATM, Gravity
**ICESat Track:** none

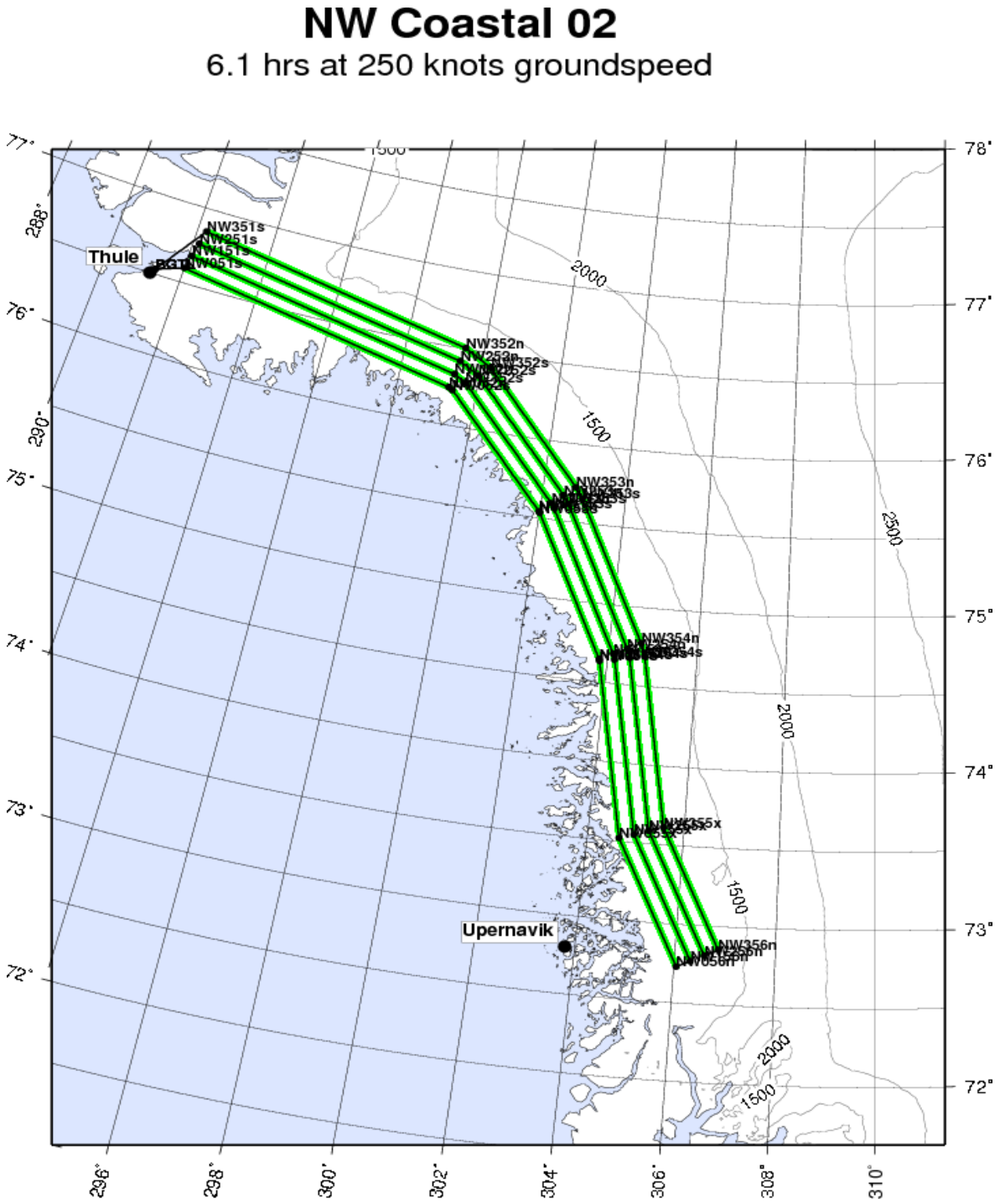


NW Coastal 02 – P-3 / Thule

This is a new mission, designed to map the near-coastal area of the upper Baffin Bay coast with a combination of all low-altitude sensors. The coast-parallel lines are separated by 10 km, and they interlace with the NW Coastal 01 mission to yield a 5 km coast-parallel grid once both missions are flown. See the "Supplementary Information" section for a map which shows how this mission relates to the "NW Glaciers" and NW Coastal 01 missions.

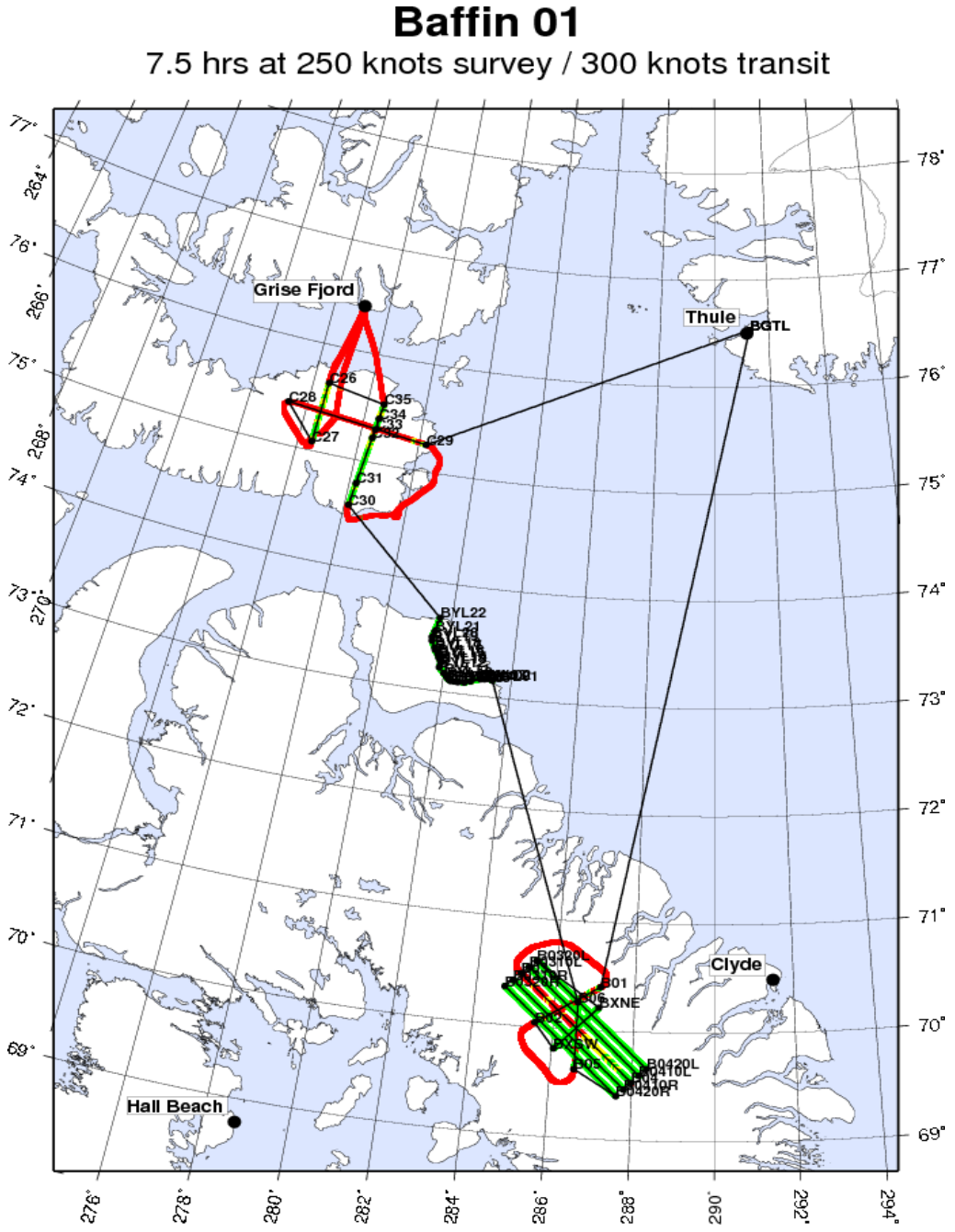
**Flight Priority:** High (to get1 of 2) **Instrument Priority:** MCoRDS, ATM, Gravity

**ICESat Track:** none



# Baffin 01 – P-3 / Thule

As currently drafted, this mission repeats survey lines over the Barnes and Devon Ice Caps previously surveyed by the ATM/KU teams in 1995, 2000, and 2005, and adds several new lines over the Barnes Ice Cap. We also survey two of the largest glaciers on Bylot Island, for the first time.
**Flight Priority:** Medium **Instrument Priority:** ATM, MCoRDS
**ICESat Track:** none

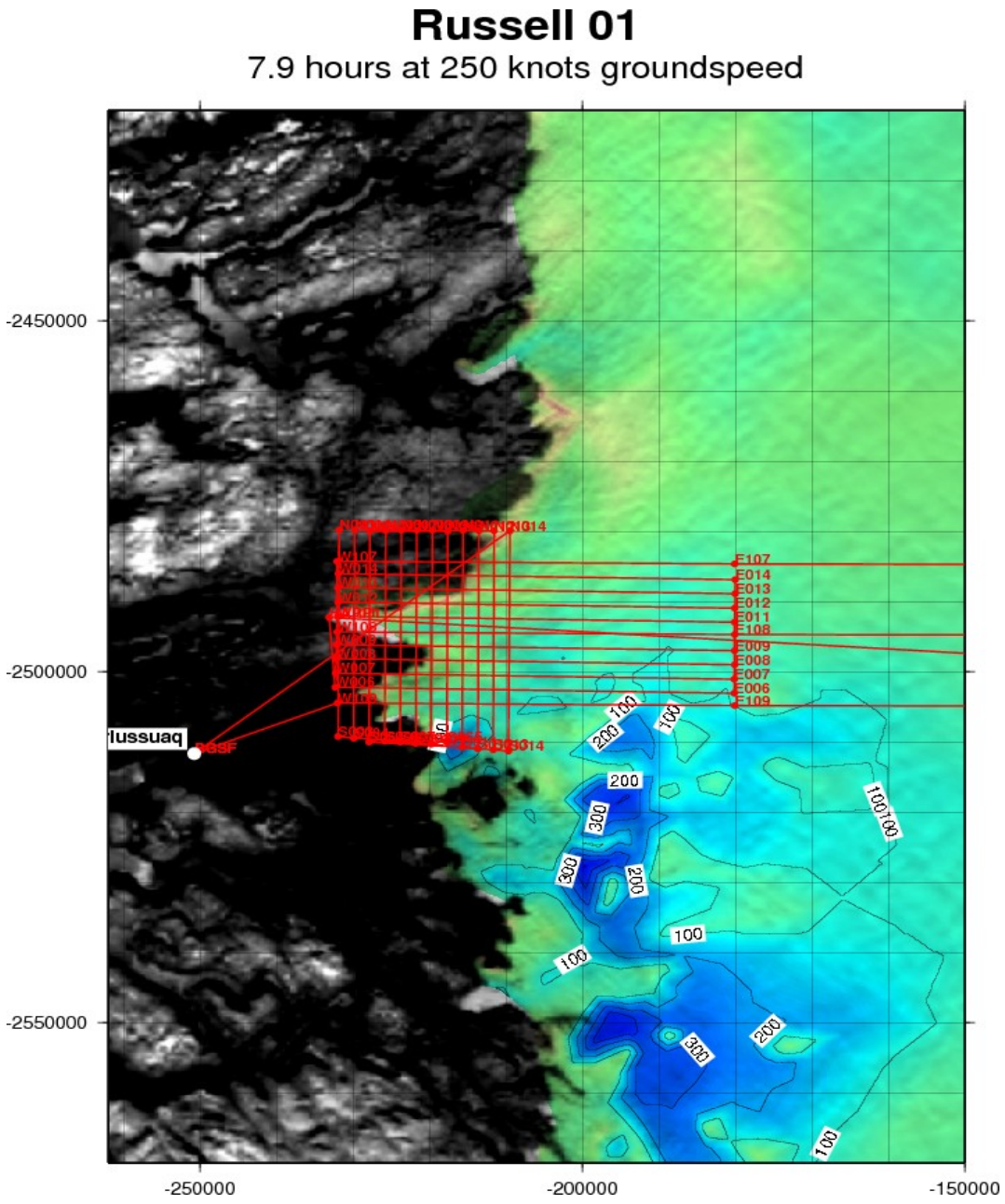


# Supplementary Information

Supplementary maps and other information follow.

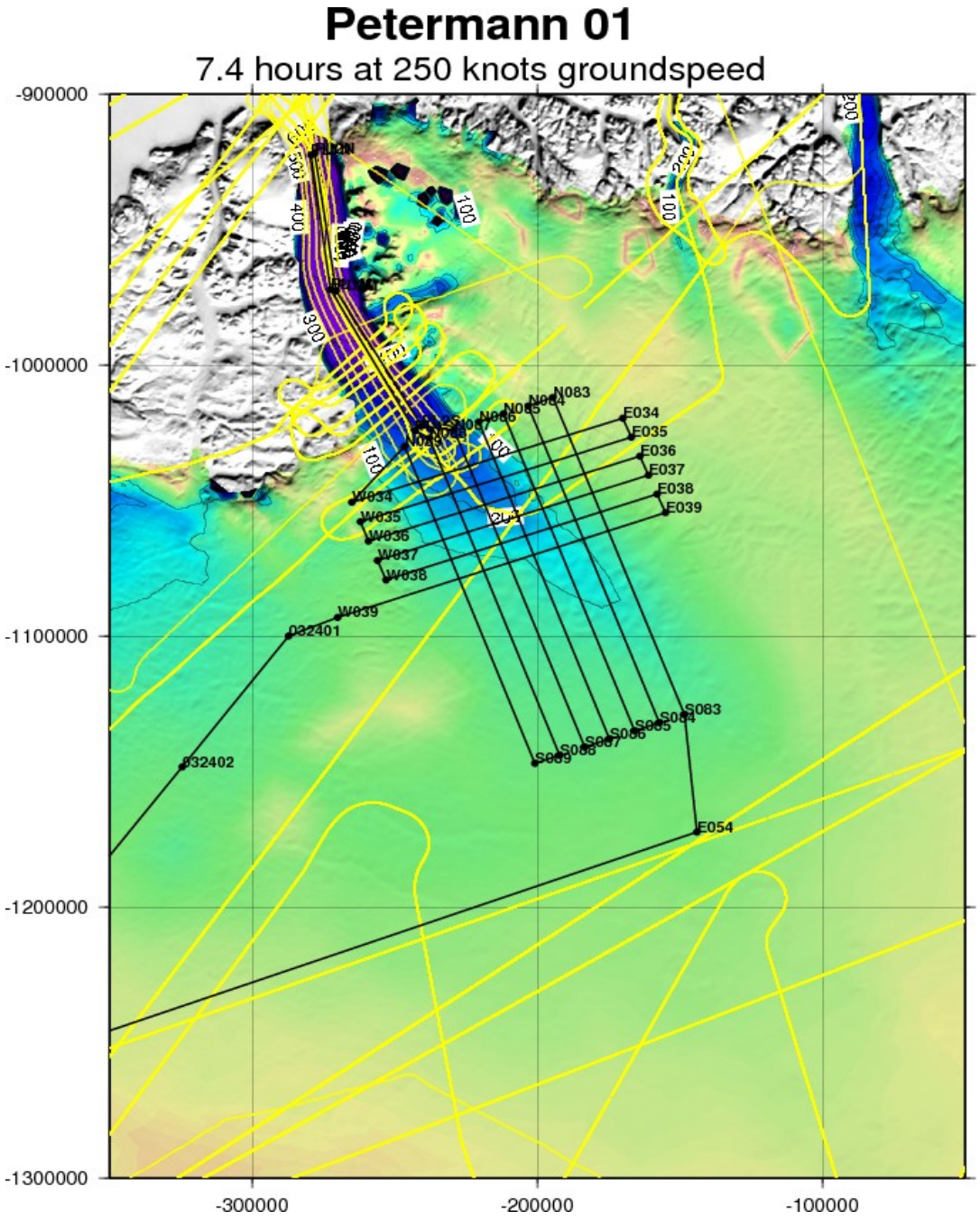
# Russell 01 detail map

This is another map of the Russell 01 bed-mapping flight, projected on the latest Rignot surface velocity map.  Of the two lobes within the grid, Russell Glacier is the southern and Isumanguata Sermia is the northern lobe.



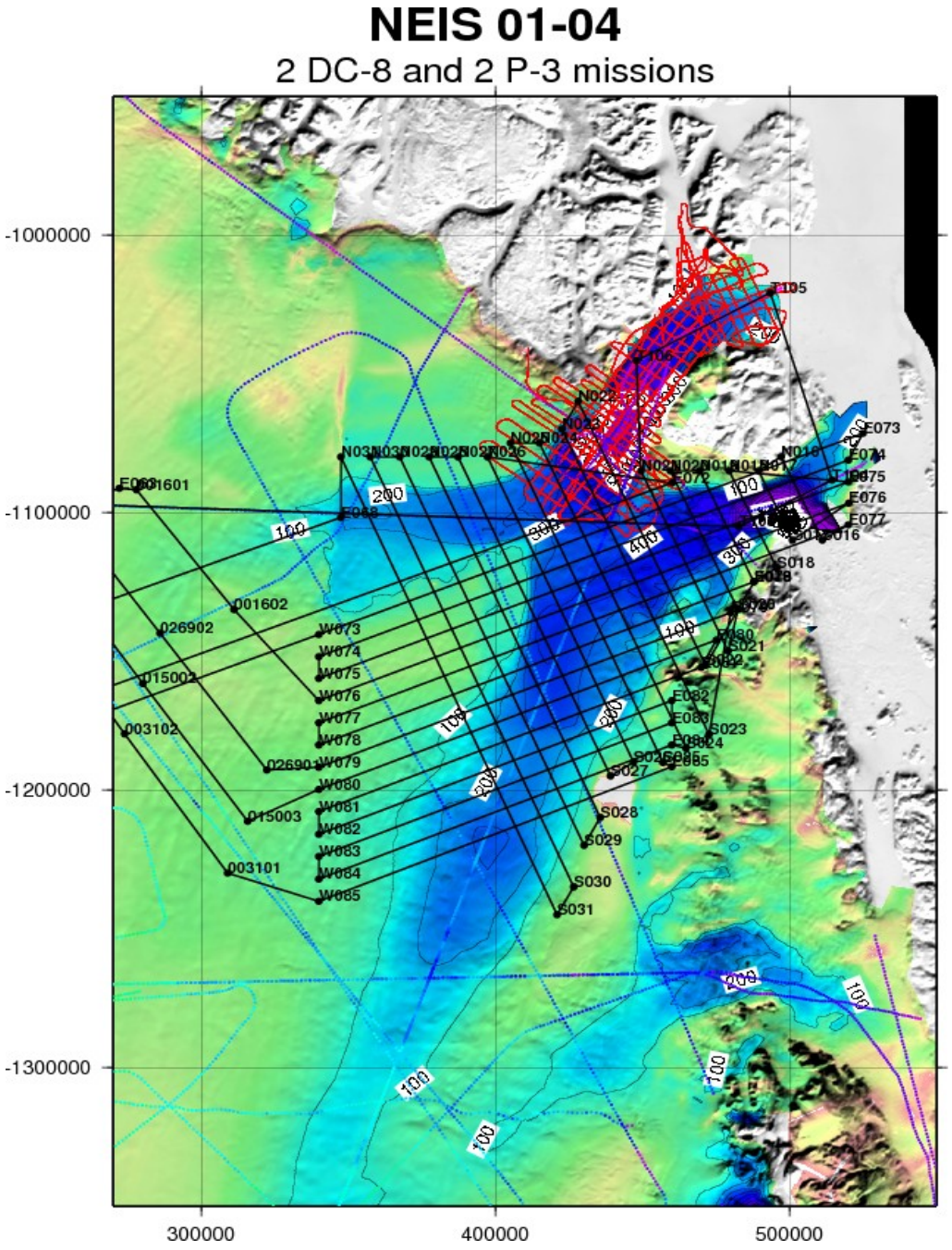
# Petermann 01 detail map

This is another map of the Petermann 01 bed-mapping flight, projected on the latest Rignot surface velocity map. 2002 ATM/KU and 2009 ICEBridge flightlines are depicted in yellow. Note that the new lines are based on the north Greenland master 10 km grid. This illustrates the occasional awkwardness that can result when local grids aligned with the flow of an individual glacier meet a master grid designed for the larger ice sheet. This mission addresses this by designing overlap between the two approaches.



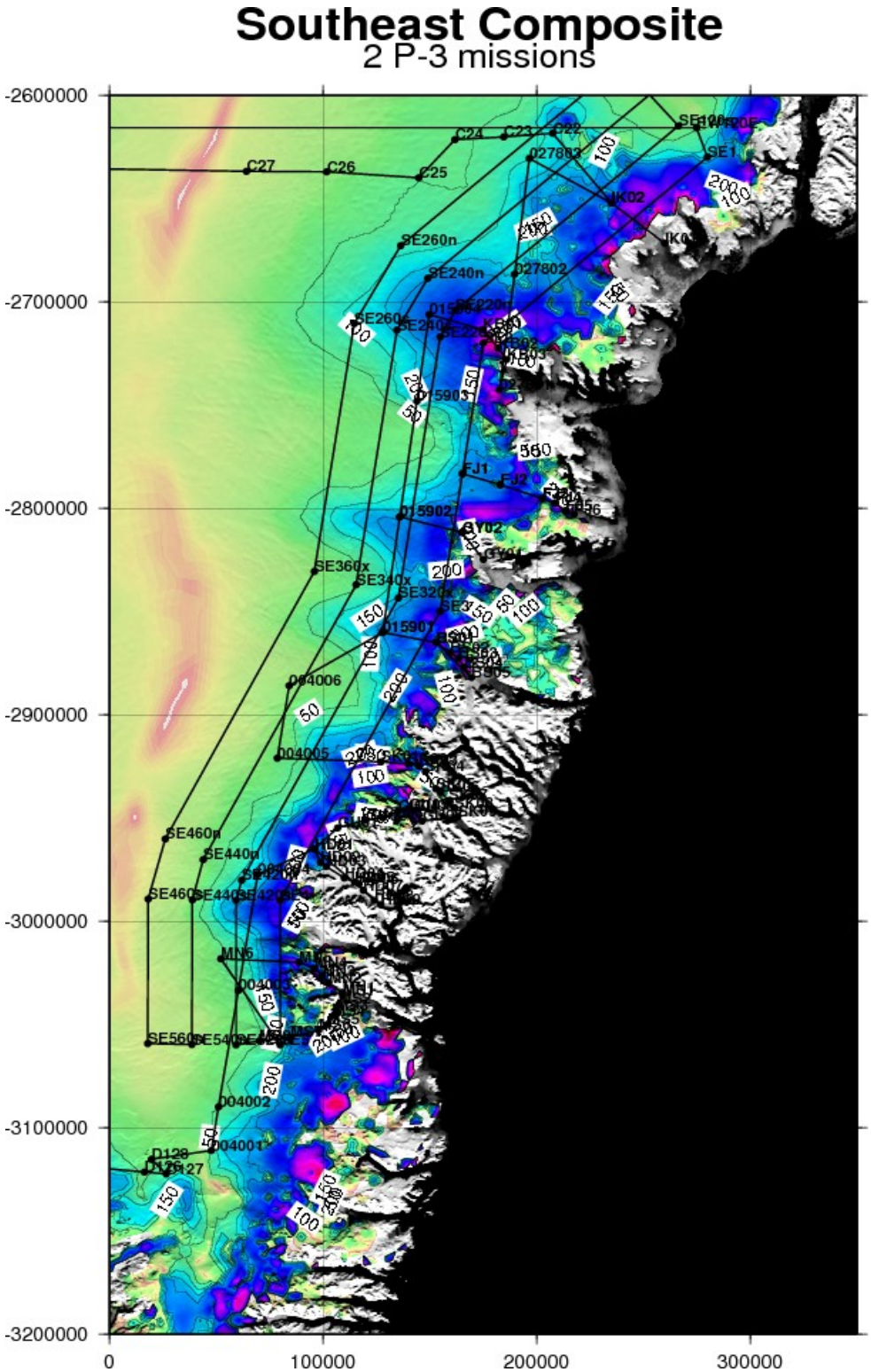
# Northeast Ice Stream detail map

This is a composite map of the four missions designed to map the lower Northeast Ice Stream and Zachariae Glacier on the 10 north Greenland master grid. The 1998 Danish flight lines, which mapped the lower 79N (Nioghalvfjerdsbrae) Glacier, are depicted in red. The NASA/KU flight lines from 1993-2007 are also depicted.



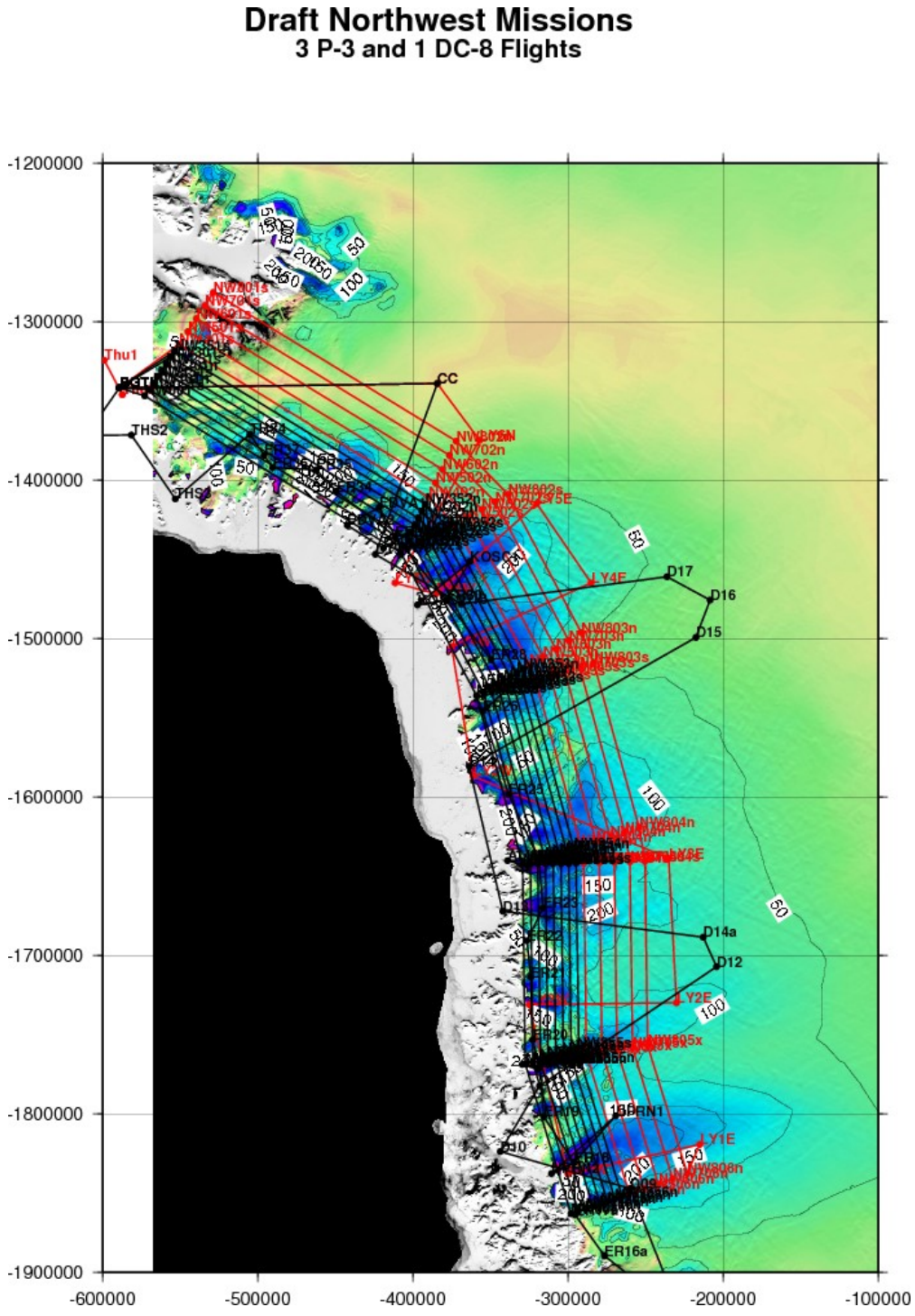
# Southeast Composite

This is a composite map of the two missions designed for the southeast Greenland coast.

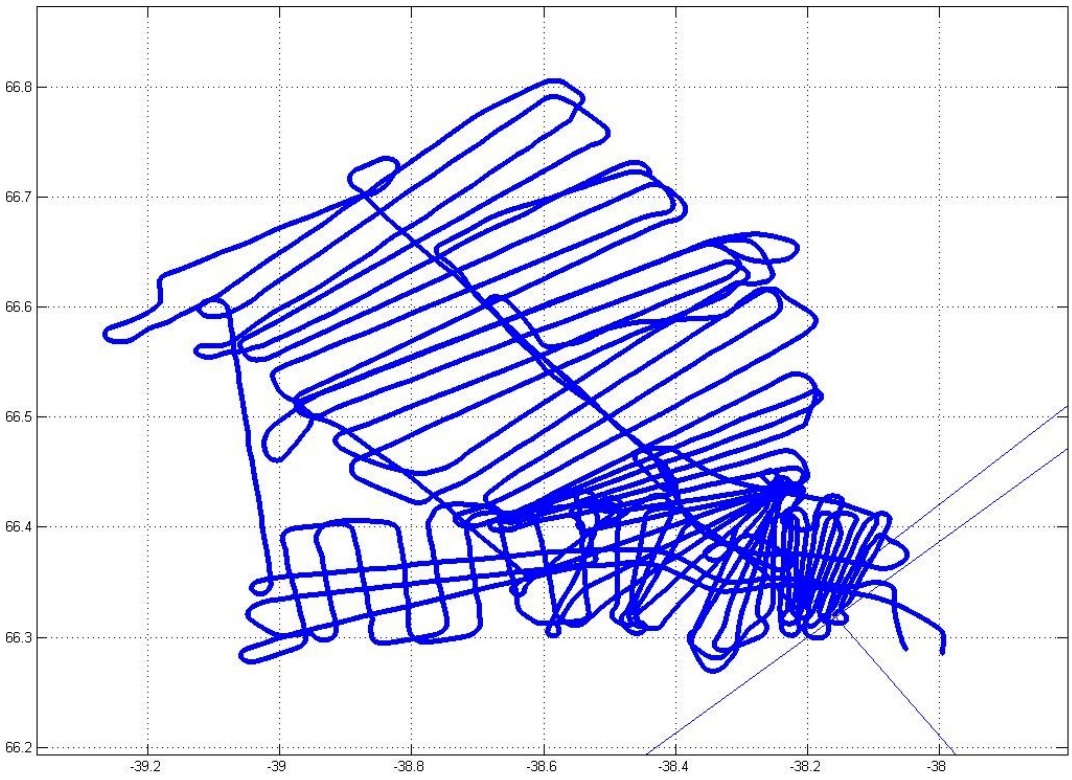


# Northwest Composite

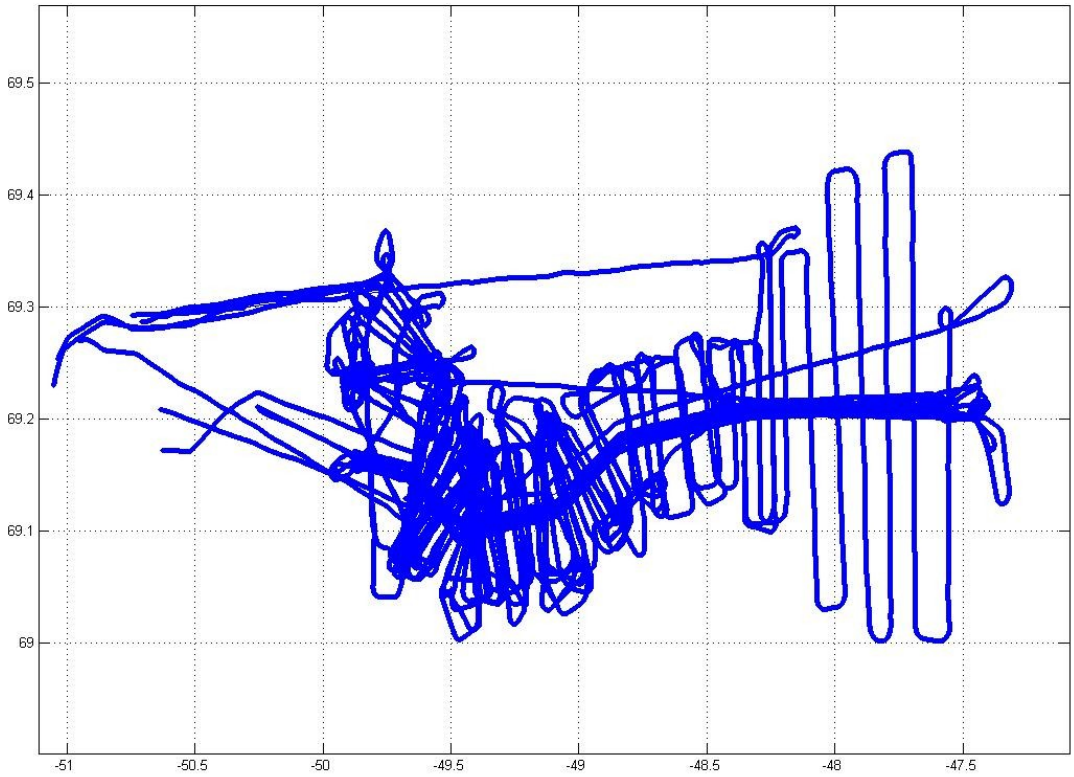
This is a composite map of the four missions designed for the upper Baffin Bay coast.



# 2009 CRESIS Helheim grid



# 2009 CRESIS Jakobshavn grid



# 2009 CRESIS Kangerdlugssuaq grid